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In This Issue:

Some Aspects of the Chemistry of Soil Colloids:

A brief discussion is presented which clarifies an understanding of the properties of soil colloids in their relation to commonly observed phenomena as may be noted by the layman but more particularly as encountered by the worker in agricultural soil research.

The discussion leads to an exposition of the modern concept of the inorganic base exchange properties of soils in that the seat of exchange resides in that soil fraction consisting of crystalline silicates of iron and aluminum. And finally that base exchange is essentially a property of molecules.

Sugar Cane Beetle Borer Trapping Experiments:

A year's systematic trapping of two small areas at Kailua shows that, probably due to a number of factors such as beetle migration and reduced effectiveness of parasites, borer population has not been reduced. Traps of split canes are most attractive during the first two weeks, and after being discarded should be destroyed to prevent the emergence of a new generation of borers developing from the eggs laid in the trap pieces.

Non-Replaceable Potash Fixation:

The fixation of potash in agricultural lands may be enhanced by artificial fertilization. The fraction so fixed may be replaceable and quite available to plant life.

However, not all fixed soil potash is necessarily present in a form which makes it a reserve supply capable of immediate utilization upon vegetative demand.

A discussion is presented in support of these premises. It is followed by a description of various conditions existing in the soil which may contribute to or favor any one of several types of soil potash fixation.

An adaptation of modern laboratory research to a practical R.C.M. study of the subject is offered in minute detail.

Fertilizer Analysis by the Spectrograph:

Results of the spectrographic analysis of twelve standard commercial fertilizers are reported. This type of analysis gives information on the mineral constitution of the fertilizers, extremely small traces of many metals being detectable.

Some twenty-one different metallic and semi-metallic elements were encountered in the course of the investigation.

The results are given semi-quantitatively. Of particular interest is the information on the occurrence of the less common plant nutrients in fertilizers—the so-called "less essential" or minor elements.

Selenium I:

Specific vegetation grown on soils of volcanic origin frequently contain selenium. Grazing animals, swine and poultry which consume seleniferous food are affected by the selenium taken into their systems. Diseases develop, many of which prove fatal.

Proof of the causal factor (selenium) in diseases of farm stock has been established but recently.

This paper presents an introductory discussion of the subject as a part of the research now in progress.

Some Insect and Other Animal Pests in Hawaii Not Under Satisfactory Biological Control:

While many insect pests in the Hawaiian Islands have been brought under excellent control by the biological method, there are still a number that have no very effective enemies and therefore do considerable damage. This article reviews some three dozen of such pests together with natural enemies that might be introduced here to help control them.

The literature cited contains over one hundred titles.

Some Aspects of the Chemistry of Soil Colloids*

By L. A. Dean
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Among the outstanding properties of soils having large numbers of particles in a fine state of subdivision are stickiness and liability to puddle when wet, and a tendency to crack and to form hard, brick-like clods when dry. Even those who are not acquainted with agricultural chemistry have observed that, during wet weather, doors are more apt to stick to door jambs; this is often the result of these properties of the clay or colloidal particles whereby the soil moves the foundations of the building.

Soils contain two types of colloids: (1) the clay, and (2) the humus. The clay is an electronegative *suspensoid,* the humus, an electronegative *emulsoid.* We might digress at this point to discuss briefly a few considerations in the classification of colloids. Zsigmondy divided colloids into two classes, those which are reversible and those which are irreversible. No sharp line can be drawn between these two classes for there are many transition cases. Gelatin typifies a reversible colloid; it may be put into solution merely by the addition of water. In this case there is no simple boundary between the phases; when water is added to dried gelatin considerable quantities of the water dissolve in the gelatin forming what might crudely be termed liquid particles (the particles become hydrated). For this reason the term "emulsoid" is often applied to this type of colloid; others prefer the terms "hydrophile" (water-loving) and "lyophile" (solution-loving). Let us now consider a solution of iron oxide particles in water as an example of an irreversible colloid. These particles may readily be coagulated and separated sharply from dilute solution. Chemical or electrical energy is then necessary to return them to colloidal solution. The term "suspensoid" is often applied to this type of colloid, as well as the terms "hydrophobe" (water-hating) or "lyophobe" (solution-hating).

Modern work with soils has indicated that the colloidal material is present in the form of a gel coating over the surface of the larger particles of primary minerals. The obvious result is that the soil as a whole is impressed by the properties of the gel coating, to an extent dependent on the proportion of colloid present. A heavy clay soil should, therefore, be regarded as consisting of a relatively small proportion of coarse and medium particles with so thick a gel coating of colloidal particles that the properties of the latter dominate the soil as a whole. A more practical example might well be the so-called abnormal soils of the Hamakua coast, the properties of which do not seem so out-of-line if their coatings are considered as predominately organic colloids of the emulsoid type.

Aside from a consideration of the physical relations and properties of soils resulting from the presence of particles in a fine state of subdivision, the role of these

* Presented at the meeting of the Hawaiian Section of the American Chemical Society, April 21, 1938.

soils in relation to the conservation of essential elements or plant foods and to their uptake by plants is very important. The relation of the important properties to the degree of subdivision of soil particles is given in Chart I, adapted from Truog.

The statement is often made that the most important property of soil colloids is their high specific surface. The law of Guldberg and Waage or, as it is commonly called, "the law of mass action," states, essentially, that the rate at which a substance will react is proportional to its "active mass." Soil chemists have often carried this law one step further and stated that the reaction rate is proportional to the "active surface," which might be considered essentially Wenzel's Law, which states that "the reaction velocity of solids with liquids is proportional to the area of contact." The following may be listed as the roles of the active surface of the soils:

(1) The solution of the essential elements in order that the needs of plants may be supplied.

(2) The removal of the soluble essential elements from a liquid to a solid phase in order that they may not be lost by leaching, especially when soluble fertilizers are applied.

The Composition of Inorganic Soil Colloids:

In 1862 Thomas Graham coined the word "colloid" from a Greek word meaning glue to identify those substances which, in solution, do not diffuse through a membrane. He named those substances which, when in solution, would diffuse through a parchment membrane as "crystalloids." This terminology in later years proved to be singularly unfortunate, for a common conception was developed that colloidal particles were amorphous masses. For many years it was popularly believed that the inorganic soil colloids or clays were mixtures of amorphous masses of iron oxide, aluminum oxide, titanium oxide, and silica. Also, the base exchange properties were attributed to adsorption on the surfaces of the particles. These beliefs were based mainly upon an inaccurate knowledge of the composition of clay constituents gathered from numerous ultimate chemical analyses.

The application of X-rays to the study of crystal structure soon showed that a number of materials commonly described as amorphous were crystalline. A notable example is cellulose which is now considered, by many, to be crystalline. In fact, many today argue that all solid matter is either crystalline or a solid solution (supercooled liquid) and the crystalline state is defined as a systematic arrangement of either molecules, ions, or atoms. That clays are crystalline in nature was first demonstrated in 1928 by Ross, whose work was followed closely by that of Hendricks and Fry. Today it is accepted by many investigators that the inorganic soil colloids or clays are mixtures of definite crystalline compounds.

The base exchange properties of soils are analogous to those of the artificial and natural zeolites which are used for softening hard water. This base exchange is considered as being a simple double decomposition reaction following the laws of stoichiometrical chemistry. The process of softening water is simply the conversion of the calcium salts of the hard water into sodium salts. This entails the changing of the zeolites from sodium to calcium salts. For many years it has been observed that only soil material in a fine state of subdivision has base exchange properties. However, it was not until the results of more recent clay investigations pointed out

The Subdivision of Matter and Resulting Properties

Size of particles,	1,000,000 $\mu\mu$	1,000 $\mu\mu$	100 $\mu\mu$	1 $\mu\mu$	0.1 $\mu\mu$
Rel. no. particles	1.	10^9	10^{12}	10^{18}	10^{21}
Rel. surface	1.	1,000	10,000	1,000,000	10,000,000

	Coarse suspensions	Colloidal suspensions	Colloidal solutions	Molecular solutions
Appearance	Very cloudy	Turbid	Clear	Clear
Particles observed	With naked eye	With microscope	With ultramicroscope	Cannot be observed
Rate of settling	Quickly or overnight	Slowly or not at all	Do not settle	Do not settle
Particles separated	With filter paper	With clay filter	With ultrafilter	Not by filtration
Diffusion and dialysis	None	None	None or very little	Very high
Adsorption	Low	Considerable	Very high	None
Rate of reaction	Low	Moderate	High	Almost instantaneous
Form on evaporation	Loose powders	Powders and gels	Gels	Crystals
Soil separates	Sand / Silt / Clay (50,000 $\mu\mu$ – 5,000 $\mu\mu$)	Clay	Ultra Clay	Soil Solution
		Soil Colloids		

Limit of microscope (ultra violet light)	100 $\mu\mu$	Diameter pores of hardened filter paper	1,500 $\mu\mu$ to 2,200 $\mu\mu$
Limit of ultramicroscope	10 $\mu\mu$	Diameter pores Chamberland filter	200 $\mu\mu$ to 400 $\mu\mu$
Limit of ultrafilter	1 $\mu\mu$	Diameter of bacteria	500 $\mu\mu$ to 1,200 $\mu\mu$
Brownian movement starts at	5,000 $\mu\mu$	Diameter 200 mesh particles	74,000 $\mu\mu$.

A cube 1 cm. on side divided to cubes 1 $\mu\mu$ on side gives a surface of 1½ acres.

CHART I.

Adapted from Truog, E., Journal of the American Society of Agronomy, 17: page 281, 1925.

what compounds made up soil colloids that it was possible to consider base exchange anything but a property of the surfaces of electronegative colloids. It is now quite generally accepted that much of the base exchange of soils finds its seat in the so-called clay minerals which are crystalline aluminum or iron silicates, the base exchange being a property of the molecules. It would thus appear that oftentimes the chemistry of the composition of colloidal particles is an important consideration.

Trapping Sugar Cane Beetle Borers at Kailua*

By R. H. Van Zwaluwenburg

To determine if the population of the sugar cane beetle borer *(Rhabdocnemis obscura)* can effectively be reduced by intensive trapping under the conditions found on windward Oahu, J. S. Rosa and the writer, with the cooperation of the Genetics department, conducted trapping experiments for a year in two fields at the Kailua substation. Standardized traps were used throughout, consisting of 30 split pieces of POJ 2878 cane; the bundles were wrapped in clean sacking with the ends tucked in loosely to make access easy for the beetles. The traps were set out early each month at fixed stations which probably varied in location not more than 15 feet at any time during the year. Collections from each set of traps were made and recorded at weekly intervals for five weeks. First collections from new traps were sometimes made on the same day that the last collections were made from five-week old ones. In such cases there seemed to be no reduction of catch in the old traps due to greater attraction by the new; old traps at best attracted very few beetles. Ten traps were maintained in each of the following fields:

Field ADA: Located in a small valley notorious for high borer population, this field contains 0.59 acre of small variety plots interplanted with POJ 2878. It was an old ratoon when last cut in April 1936 and had been abandoned. Random trapping to get material for another experiment had been carried on in this field for about six weeks before the experiment began. Across the road, to the east of ADA, is Field ADC, an area of 2.5 acres last cut on May 11-12, 1937, and still maintained as a ratoon.

Field G-6: This is about two acres of small variety plots interplanted with POJ 2878; it is first ratoon, last cut in June 1936. About midsummer of 1937 it was abandoned and no further attention was given it by the agriculturists. No trapping was done prior to the start of the experiment. The trapping stations in this field were located along the eastern edge of the field next to a small stream, protected from prevailing winds by a high, wooded bank. Three of the stations were in a low area which was flooded once or twice during the year.

Between February 20, 1937, when the first collections were made, and March 9, 1938, when the last collection was made from traps set out February 2, 1938, a total of 27,027 beetles was captured; 16,476 were from Field ADA, and 10,551 from Field G-6. Omitting the figures from the February 1937 traps (because of incompleteness), ADA yielded 14,755 beetles (7,535 males and 7,220, or 48.9 per cent, females), and G-6, 9,449 beetles (5,004 males and 4,445, or 47.0 per cent females). In the following summary of the catch in each field, the figures are the average total per trap of five collections from traps set out in the months indicated; these figures are shown graphically in Fig. 1.

* The statistical evaluation of the conclusions reached in this study was made by L. R. Smith and others of the Agricultural department.

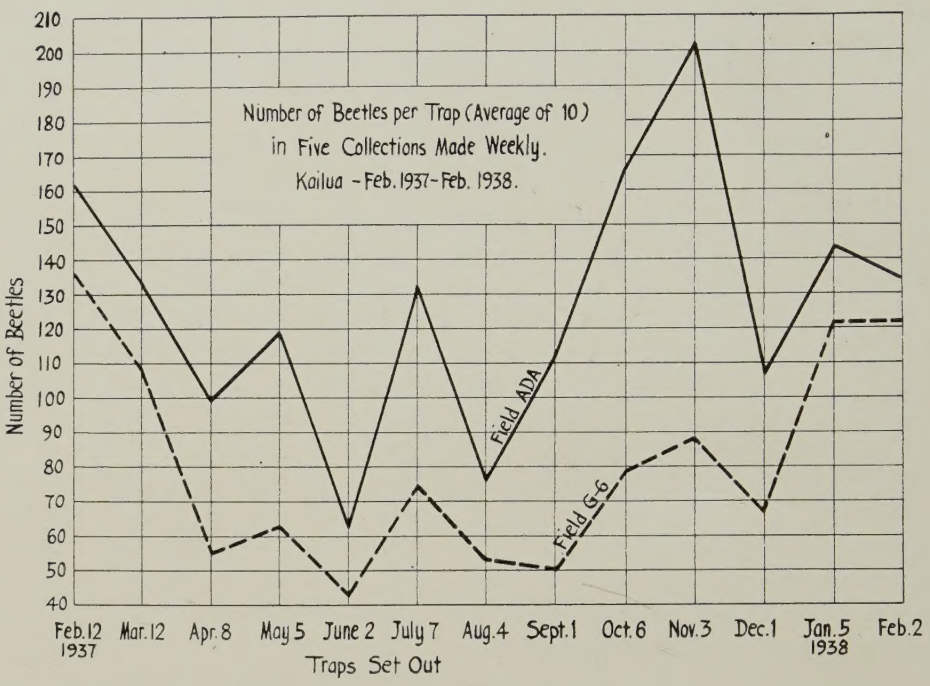

Fig. 1

Month in which traps were set out	Field G-6			Field ADA			Avg. mean temp. F.
	Total	Male	Female	Total	Male	Female	
February 1937	136.6	?	?	161.4	?	?	68.3
March	107.5	67.5	39.9	132.9	69.8	62.2	72.4
April	55.0	33.4	21.0	99.5	47.1	51.4	72.8
May	62.8	33.7	29.1	119.4	55.8	62.9	73.5
June	42.6	23.7	18.7	62.5	31.1	31.4	75.9
July	74.3	30.8	43.5	131.7	56.9	74.8	76.2
August	52.3	23.1	28.8	75.8	37.6	38.2	76.1
September	49.8	23.0	26.5	112.1	51.8	57.7	75.8
October	78.1	36.0	41.7	167.0	85.4	80.3	75.4
November	87.8	41.9	44.7	202.8	109.1	93.3	73.2
December	66.0	37.1	22.8	106.0	55.7	50.1	70.1
January 1938	121.2	64.4	55.3	143.1	82.8	59.6	71.8
February	121.1	58.9	61.2	133.4	71.9	60.5	71.7

These figures seem to show, in spite of wide variations, a trend toward a greater number of beetles in winter than in summer. Heavy catches of beetles seem to be associated with hot, still, humid weather, but unfortunately relative humidity data for Kailua are not available for correlation with our figures.

To reduce the borer population to a reasonable level it is necessary to attract the beetles already accumulated in the field when trapping begins, as well as those which form the natural month-to-month increase in the population. This requires that traps be more attractive to the beetles than the standing, broken and rat-eaten

cane present, and that there be no considerable immigration of beetles from outside areas.

From the figures tabulated above, it is apparent that the year's trapping failed to reduce greatly the borer population in either of the experimental fields. In ADA, where preliminary trapping may have reduced the accumulated population already present when the experiment began, the difference between the first and last totals (February 1937 and February 1938) is greater than in G-6 where the absence of preliminary trapping should presumably have resulted in the larger before-and-after difference.

One factor, concerning which little definite is known, and which may be more important than originally believed, is the distance to which adult borers migrate, or are attracted, under field conditions. Marked beetles have been recovered in traps at a distance of 650 feet from standing cane in which they had been released less than six weeks before. Recently, beetles of both sexes have been trapped under circumstances which make it certain they had left standing cane and travelled across open areas for distances up to 150 feet. In some cases there was no cane whatever (except the trap itself) in the direction they had traveled, and it seems probable that at least a few beetles are leaving cane areas more or less continually.

If cane is disturbed, as in harvesting, or if no cane is present, it is to be expected that beetles may migrate considerable distances. This is suggested by the following figures from ADA, in which the increased catch in the week-old traps on May 12 may have resulted from cutting the nearby ADC (without burning) on May 11th and 12th:

Traps set out April 8		Traps set out May 5	
April 14	21.7 beetles per trap	May 12	44.8 beetles per trap
April 21	28.9 beetles per trap	May 19	33.4 beetles per trap
April 29	29.8 beetles per trap	May 26	21.0 beetles per trap
May 5	13.3 beetles per trap	June 2	14.3 beetles per trap
May 12	5.8 beetles per trap	June 9	5.9 beetles per trap

That the effectiveness of the Ceromasia parasite of the borer is reduced by cane falling over, or by heavy trash and weed cover, is well recognized. To what extent the tachinid's effectiveness was thus impaired in this experiment is not known; but both fields were untended for most of the experiment—honohono (Commelina) thrived, and the cane lodged badly. The result was a condition unfavorable to effective control by parasites, to a degree that would not have occurred under plantation routine.

Traps show a definite loss of attraction for beetles after the second week (see Fig. 2). The following data are a summary of results from both fields; the first collections were made when traps were one week old, the second when they were two weeks old, etc.:

	Number of beetles	Per cent of total
1st collection	7552	31.0
2nd collection	8320	34.2
3rd collection	5039	20.7
4th collection	2318	9.5
5th collection	1075	4.4

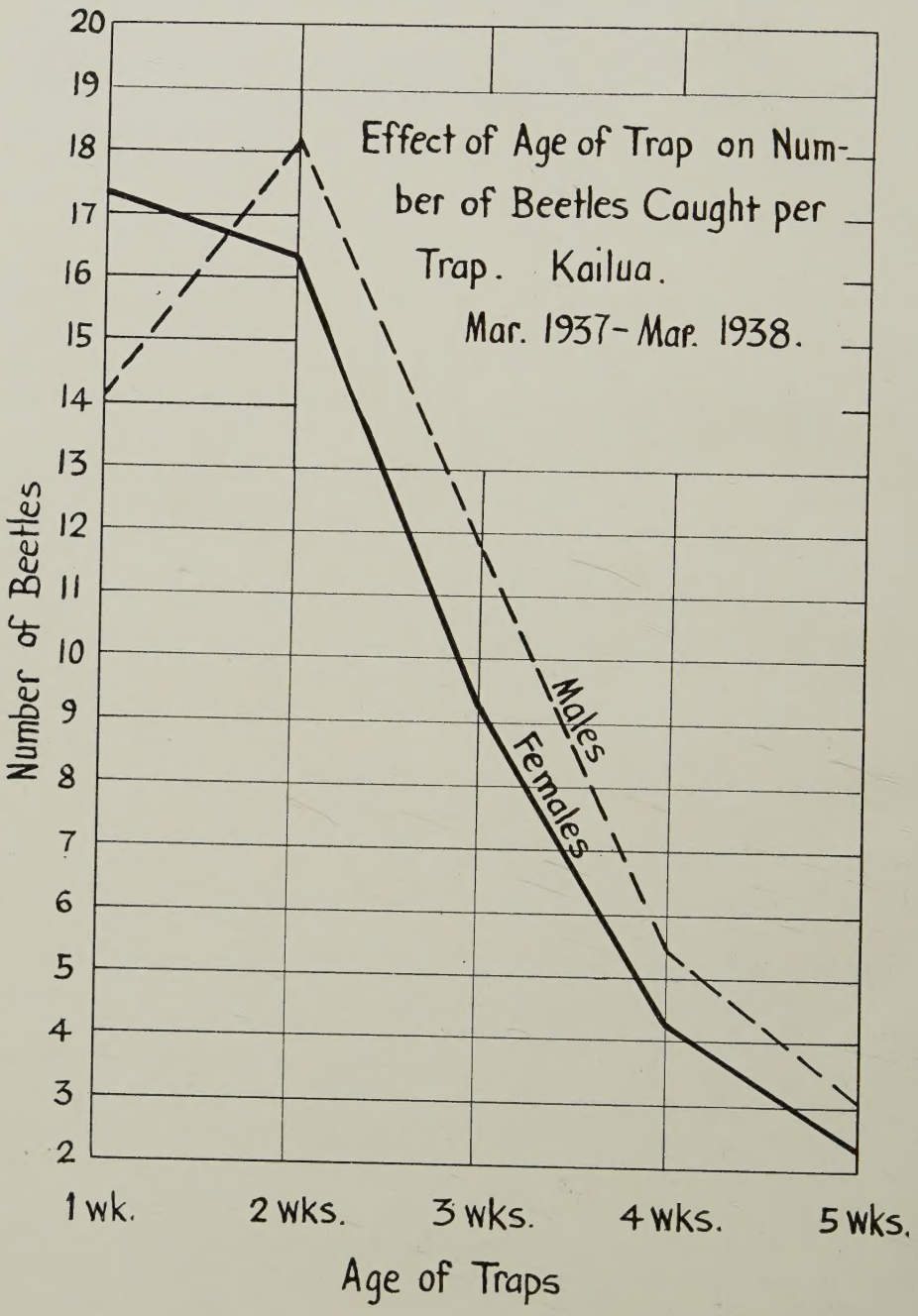
Effect of Age of Trap on Number of Beetles Caught per Trap. Kailua.
Mar. 1937 - Mar. 1938.
Number of Beetles
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
Males
Females
1 wk.
2 wks.
3 wks.
4 wks.
5 wks.
Age of Traps

Fig. 2

Nearly two-thirds of all the beetles were caught in the first two weeks, and 86 per cent in the first three. By sex, the catch was:

	Number of males	Number of females	Per cent females
1st collection	3396	4156	55.0
2nd collection	4388	3932	47.2
3rd collection	2823	2216	43.9
4th collection	1303	1015	43.7
5th collection	629	446	41.4

In general, the females outnumbered the males during the first week, although in a few cases females predominated in later collections. The increase in beetles of both sexes in the two-week old traps was also fairly consistent, and was due to a large increase of males. Whether males are less strongly attracted to the traps, or are really attracted by the females present, rather than by the traps themselves, is not apparent.

There is a moderate trend, without statistical significance, for the ratio of females to males to be higher in summer and fall than in winter (see Fig. 3). The following figures indicate the numbers captured within each calendar month (not the month in which the traps were set out):

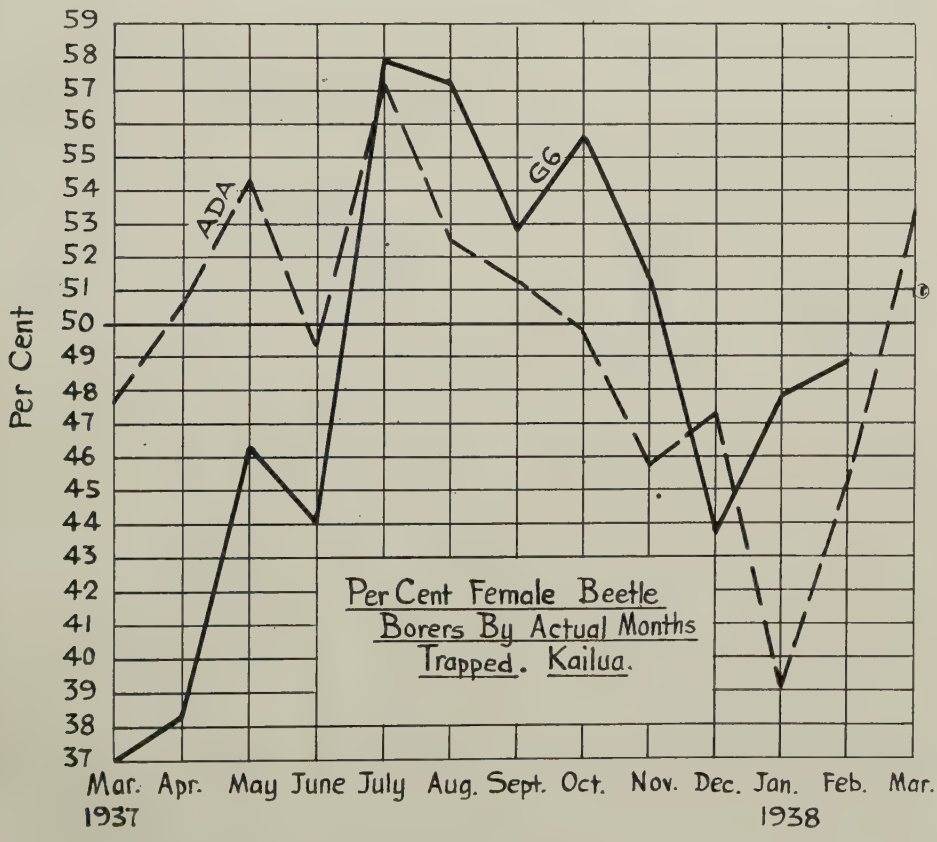

Fig. 3

	Field G-6			Field ADA		
	Males	Females	Per cent females	Males	Females	Per cent females
March 1937	846	497	37.0	607	556	47.8
April	388	241	38.3	470	482	50.6
May	342	295	46.3	536	641	54.4
June	264	209	44.1	401	390	49.3
July	288	397	57.9	508	682	57.3
August	220	295	57.2	378	419	52.5
September	260	291	52.8	569	600	51.3
October	308	386	55.6	714	710	49.8
November	432	457	51.4	1131	956	45.8
December	353	274	43.7	542	490	47.4
January 1938 ...	511	470	47.9	696	497	39.1
February	694	666	48.9	823	683	45.3
March	...	...	...	497	571	53.4
April	...	...	...	743	848	53.2

The greatest benefit from trapping is to be expected only if traps are destroyed as soon as they no longer attract borers. A new generation of beetles will develop in canes left lying in the field, the result of eggs laid while the traps were still attractive to the females. In the laboratory, fourteen beetles completed their development in an old trap within 15 weeks of its first being set out, in spite of the extreme dryness of the cane. In the field, with better moisture conditions, even more borers might have reached maturity from similar discarded traps.

Weekly examinations were made by F. A. Bianchi of female beetles collected from September into March, to determine the number of mature eggs present in each. The average was 4.2 eggs per female; and that comparatively few eggs mature at a time is to be expected among insects which lay large numbers of eggs over a long period (upwards of 600 in about a year in the case of this beetle). The number of mature eggs varied from 0 to 17. No seasonal difference in egg complement could be detected for the period during which examinations were made, nor were females from fresh traps better or worse supplied with mature eggs than those from old traps.

Conclusions

1. A year's trapping apparently failed to reduce the borer population to any marked extent. This may have been due to one or more causes: migration of beetles from outside areas; failure of the traps to attract borers in competition with broken and rat-eaten cane; or the probably reduced effectiveness of the tachinid parasite under the conditions of the experiment.

2. More beetles were usually attracted to traps during the second week than at any other period. The catch obtained in the fourth and fifth weeks was so poor as to suggest that more beetles might have been collected if traps had been renewed every three weeks instead of every five.

3. Although the figures show an apparently higher catch of beetles in winter than in summer, such a conclusion is contradicted by evidence obtained so far in a second year of trapping. We believe one or more additional, unrecognized factors influence the borer population to a degree perhaps equal to that of the seasonal influence.

4. Female beetles are most strongly attracted to traps during the first week; males, during the second week.

5. The ratio of females to males tends to be somewhat higher during the summer months, although the trend is not statistically significant.

6. No correlation was apparent between borer population and either temperature or rainfall; but, because it takes from three to four, or more, months for this insect to develop from egg to adult, a lag is to be expected in any correlation between population and the climatic conditions operative some months before.

Non-Replaceable Potash Fixation

By Clarence Lyman*

Potassium occurs in soils in forms which are water soluble, those from which it is replaceable, and largely as the silicate minerals which are predominately the feldspars (orthoclase and microcline), and the micas (muscovite and biotite). The potassium so present, like phosphorus, may be classified as readily available and difficultly available and, with the exception of the soluble portion, is said to be fixed.

Into the category of the readily available potassium falls the soluble form and that held in the base exchange material. The difficultly available forms of potassium include the minerals from which the nutrient cannot be replaced by a weak acid or a salt solution, but from which the potash is only slowly available to the plant in the order of biotite, orthoclase, muscovite, and microcline (*7*) and others, in amounts insufficient for proper growth.

The availability of essential soil elements being a relative matter, it is conceivable that the liberation of potash by the decomposition and hydrolysis of the potassium-bearing minerals can be reversed, as shown in the following empirical reactions, by the presence in the soil solution of an excess of potash such as results subsequent to fertilization:

$$2H_2O.K_2O.3Al_2O_3.6SiO_2 \underset{+HOH}{\overset{\text{Heat + Pressure}}{\rightleftharpoons}} 2KOH + 3\ 2H_2O.Al_2O_3.2SiO_2$$

(Muscovite) (Kaolinite)

$$K_2O.Al_2O_3.3SiO_2 \underset{-2HOH}{\overset{+2HOH}{\rightleftharpoons}} 2KOH + H_2O.Al_2O_3.3SiO_2$$

(Microcline or Orthoclase) (Alumino-silicic acid)

$$K\text{—Zeolite} + HOH \rightleftharpoons H\text{—Zeolite} + KOH$$

Such reactions have long been considered outlets for the stabilization of the potassium balance in soils where leaching is not a preponderant factor.

This is substantiated by the work of Volk (12), who showed that under meteorological conditions of alternate wetting and drying, the readily available potassium in some soils becomes fixed to some degree in a non-replaceable form. When these soils were kept continually moist, however, very little fixation of this kind took place.

To facilitate discussion, the term "potash fixation" as used throughout the remainder of this paper will refer to the non-replaceable form of fixation.

By means of mineralogical, chemical, and X-ray analyses of a soil possessing high potash fixing properties, Volk concluded that fixation of this constituent resulted when a portion of the applied potash reacted with some of the colloidal alumi-

* Senior, University of Hawaii. Through special arrangements with the University, the experimental work reported in this paper was entirely confined to the direction of Dr. F. E. Hance, Chemist, Experiment Station, H.S.P.A.

num silicates present to form muscovite as a secondary mineral. This conclusion is not accepted by all soil investigators (3).

Volk has demonstrated that the amount of potash fixed varies with each soil and between the limits of zero per cent and 100 per cent of that added. The factors that affect the percentage of fixation in a given soil are shown to be the temperature of drying, the number of alternate wettings and dryings, the form of the potassium compound added (12), the amount of potash added (12, 10), and in some cases, the amount of calcium and magnesium present (12, 3, 5, 6, 10).

Preliminary work involving a number of potash, lime, and phosphate fertilization practices (Table II) and the extensive research of the highly conflicting literature indicate an absence of any general connection between the effects of non-potash fertilizers on a series of soils and the resultant fixation of potash or its liberation to the replaceable form.

On certain soils lime decreases the solubility of the non-replaceable potassium, while on others no effect (12, 9, 5), or a slight liberative effect is evidenced (1).

A conclusion which may be drawn from the divergent findings of Volk (12), Joffe and Kolodny (3), and Abel and Magistad (1), is one suggested by the work of the last two and by the findings of Peech and Bradfield (9). This is the highly probable effect of the fertilizer compounds on the base exchange material of the soils, the pH subsequent to fertilization, and the degrees of antagonism and common-ion effect.

For the purposes of comparison, and to cover as wide a range of fixation as possible, samples of local and mainland soils were obtained. Sources of sugar cane soils were the Waipio, Manoa, and Hilo substations of the Experiment Station, H.S.P.A., and cultivated and uncultivated Olaa areas. In addition, a sample of Superior clay collected in Ashland, Wisconsin; one of Miami silt loam from Dane County, Wisconsin; a series of samples from a profile of Manana silty clay loam taken near Waialua, Oahu; a residual Kohala soil extremely high in readily available potash; and a Kona coffee area soil were obtained.* Of these last named, the local ones were all from uncultivated areas.

Ten-gram samples of the soils were impregnated with potash in the form of a solution of the chloride, to the extent of 1,400 pounds per acre-foot of 2.5 million pounds of weight.† These were then subjected to stimulated atmospheric conditions of alternate wetting and drying by being set in a constant temperature water bath adjusted to maintain a temperature of 70° C.,‡ and on reaching dryness, dampened with measured volumes of distilled water. For a maximum fixation at this temperature, the procedure was repeated for a total of ten dryings, although tests show that

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* The writer is indebted to Dr. L. A. Dean of the Hawaii Agricultural Experiment Station for contributing these soils, of which the local samples, excepting that from Kona, were collected by the U. S. Department of Agriculture Soil Survey party.

† This rate of fertilization was arbitrarily chosen to keep the maximum amount of available potash within the maximum limits of the R.C.M. of determination without necessitating the dilution of the extract.

‡ It should be noted here that the temperature used is not far-fetched, for, when actually determined, the surface soil of the Makiki field was found to be heated to a temperature greater than 65° C.

from 60 per cent to 84 per cent of the amount fixed is so removed from the available class by a single drying.

Using a ratio of 1 ml. of water to each gram of impregnated soil "weathered" in a 250-ml. beaker, the period of heating necessary for drying to friability was found to be about an hour.

In duplicate the readily available potassium was then determined volumetrically by the permanganate titration of the sodium cobalti-nitrite precipitate (13), and turbidimetrically by the recently modified method for the rapid determination of potash in soils. (Chemistry Department, Experiment Station, H.S.P.A.)

As a basis for determining the per cent of the total readily available potash present that became fixed as a result of the weathering process, blanks were prepared by adding the same amount of potash, in the form of a highly concentrated solution, to the required amount of the extracting solution used.* Care was taken to keep the total volume of the mixture to that necessary to maintain the soil-water ratio of each procedure. The mixture was then added to other portions of the same soil samples, followed by the immediate extraction and subsequent determination of the replaced potassium.

Before satisfactorily comparable results could be obtained, a number of refinements of the procedure for the turbidimetric analysis were found to be necessary.

Due to the inconsistency of the volume-weight method of measuring soil samples, analyses by this means were conducted on weighed samples.

In making turbidimetric readings by the conventional method, the failure to note more than one of the various acceptable readings obtainable with varied aliquots of extract introduced deviations of as much as 125 pounds of potash per acre-foot. Similarly, the failure to differentiate between a high 2 reading and a low 3 reading was found to increase errors between 14.2 per cent and 18.1 per cent.

It was originally felt that it would be necessary to employ a special potash chart to overcome the latter form of errors, and several of these, having less divergence in the thicknesses of the successive lines, were prepared. Later, however, a system of cross checking on the data sheet was devised and found to be entirely satisfactory. By this system, all successive aliquots giving acceptable readings in the range of a low 2 to a high 3 are noted, and the mean of their values in terms of 2 and 3 readings calculated. Results so obtained closely approximate the actual in pounds per acre-foot as determined with standard solutions.

With the incorporation of these refinements in the turbidimetric procedure designed by E. K. Hamamura,† the results shown in Table I were obtained.

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* All extracts analysed by the volumetric method were prepared by using a 1 Normal solution of ammonium acetate adjusted to a pH of 6.8 and applied in a soil-water ratio of 15 ml. per gram.

† Assistant Chemist, Experiment Station, H.S.P.A.

TABLE I

SOIL SAMPLES INCLUDE:

Manana Silty Clay Loam (MnDK), Hilo Substation (H), Kona Coffee area (K), Kohala Residual (KOH), and Waipio Substation (W)

Sample	Per cent fixation by titration	Per cent fixation by turbidimitry
MnDK 1000	18.8	19.5
MnDK 1001	18.1	17.5
MnDK 1002 (Hardpan)	11.3	18.7
MnDK 1003	17.3	18.7
MnDK Hardpan duplicate at depth of 1001	15.2	10.5
MnDK Partly decomposed rock at 30 feet.	22.1	22.0
H 12523	17.0	14.3
H 12524	20.0	18.7
K	00.0	00.0
W Field 37, surface	00.0	00.0
KOH	00.0	00.0

The results tabulated above are from a long series of determinations, many of which were discarded due to extreme variations caused by the need for the refinements in the turbidimetric procedure described elsewhere. Table I is meant to manifest the practicability of the use of the turbidimetric procedure under the proper conditions of control.

With proof that the degree of potash fixation in soils could be satisfactorily determined by means of the Rapid Chemical Method of the Experiment Station, H.S.P.A., an attempt was made to adapt the procedure used in the research laboratory to the plantation laboratory. The greatest problem in this adaptation was obviously the regulation of the temperature of "weathering" to standard conditions without involving the use of an expensive constant temperature water bath such as is available at the Station. A study of the situation revealed that the heating equipment possessed by the R.C.M. laboratories of the agriculture departments of the plantations was for the most part limited to one of the several types of hot plates supplied by the Chemistry department of the Station. Each type was found to have a different capacity, correspondent to the variant voltages maintained by each plantation.

An attempt was made, therefore, to correlate the degree of fixation with the temperature of heating. A number of samples were placed on an asbestos-covered hot plate heated a "low heat."* The procedure as previously described was then applied, and turbidimetric determinations made at the end of five and ten dryings. No increase in fixation was found to have taken place after the fifth drying, but the determinations showed an increase of from 200 to 400 per cent of the fixation at 70° C.

It was evident from this that such a treatment would give the maximum fixation possible, but under conditions of heating not existing in the fields. As with the single drying, no correlation was possible.

* For this particular hot plate, it was found to be about 95° C. It was noted that the temperature of the heated soil remained at 70° C. until nearly dry, rising to 95° C. as the amount of evaporation decreased.

Attention was then diverted to stabilized heating through the use of water and sand baths. Tests run involved the use of a flat-bottomed pan placed on a hot plate and filled to the depth of one-half inch with sand. Uneven surface heating was evident, but the per cent fixation was in fair agreement with that of the constant temperature water bath.

The best correlation was found possible through the use of a water bath placed on a hot plate. The maximum temperature of the water in the bath at low heat was found to be slightly greater than desired, but the use of asbestos sheets under the pan was found to remedy the situation.

It was concluded that for plantation use, the necessary amount of insulating material to be used could only be determined on the premises, due to the differences in the heating capacities of the various hot plates in use. The temperature to which the bath* is adjusted should be approximately 72° C., allowing a drop of 2° C. in the transmission of heat through the beakers. A wire basket suspended from the upper edge of the water bath and submerged to a depth of ¼ inch serves to keep the beakers off the bottom of the pan.

The optional method for the rapid determination of potash in soils as adapted for the determination of the degree of potash fixation in soils is here given.

The Rapid Determination of Irreplaceable Potash Fixation in Soils

Equipment Required:

1 Tortion or platform balance, accurate to 0.00 1 gm.
1 Aluminum weighing dish with counterpoise, size 19.
2 Burettes, dispensing, 250-ml. capacity.
2 Covers for 250-ml. dispensing burettes.
24 Flasks, Erlenmeyer Pyrex, 125-ml. capacity.
24 Beakers, Pyrex glass, 50-ml.
12 Beakers, Pyrex glass, 250-ml.
12 Glass stirring rods, 5 inches long.
1 Water bath, constant level, 12″ x 24″.
1 Electric hot plate, 12″ x 24″.
4 Sheets of asbestos paper, cut to fit hot plate.
1 Thermometer, —10° C. to 110° C.
24 Funnels, glass, short stem, 65-mm. diameter.
4 Pkgs. Munktell No. 3, 11-cm. filter paper.
24 Vials, shell, short form.
1 Pipette, Mohr, 2-ml. calibrated to 0.01 ml.
1 Pipette, Mohr, 1-ml. calibrated to 0.01 ml.
1 Pipette, Exax volumetric, 5-ml.
2 Burettes, Exax, 50-ml.
2 Covers, for 50-ml. burettes.
1 Adapter for the burette containing Reagent No. 2 K_2O.
2 Inclined vial block supports.
1 Potash rotator, electric.

* A constant level water bath may be obtained at a small cost.

2 Supports, iron, 6″ x 9″.
1 Clamp, burette, Lincoln.
1 3-foot section of 5-mm. rubber tubing for use with distilled water dispensing burette.
1 Pinchcock.
2 Clamps, castaloy, large, with rubber-covered jaws.
1 Funnel support, 10 holes.
1 Spatula, stainless steel, 4-inch blade.
1 Dropping bottle, amber, pipette stopper with knob at tip, 30-ml.
1 Gal. Reagent No. 1 K_2O.
¼ Pint Reagent No. 2 K_2O, in glass-stoppered bottle.
1 Pint Reagent No. 3 K_2O.
1 Pint K_2O Fixation Solution No. 1.
½ Pint K_2O Fixation Solution No. 2.
1 Gallon distilled water.

Remarks:

Although it is doubted that fixation will exceed 33 per cent of the amount of potash added, provisions are made for the determination of fixations up to 81 per cent. For this purpose, two potash fixation solutions are provided.

This procedure may be adapted to potash fixation studies under various fertilization practices.

Procedure:

1. Weigh 10.0 grams of the soil samples to be tested, placing in duplicate, one set in marked 250-ml. beakers, and the other set in marked 125-ml. flasks.

2. (*a*) To each flask containing 10.0 grams of soil add 28 ml. of Reagent No. 1, K_2O, pipette 2 ml. of Potash Fixation Solution No. 1 into each flask.

(*b*) Swirl for ½ minute. Filter through Munktell No. 3, 11-cm. filter paper into clean 50-ml. beakers.

(*c*) By means of a 1-ml. Mohr pipette, transfer two 0.5-ml. portions into each of two potash vials.

(*d*) Deliver 0.5 ml. of Reagent No. 1, K_2O, from a 50-ml. burette into each vial, making the total volume of the liquid in each up to 1 ml.

(*e*) Add four drops of Reagent No. 2, K_2O, to each of the vials and mix thoroughly.

(*f*) Immediately introduce 1 ml. of Reagent No. 3, K_2O, from a 50-ml. burette, provided with the special adapter at the tip, placing the vial on a block support with the tip of the adapter touching the inner wall of the vial. Turn the stopcock on full, and allow 1 ml. of the reagent to run onto the solution in the vial. Two distinct liquid layers should be visible. In case the layers are broken or a cloudiness appears between them, discontinue and repeat steps 2 (*c*) to 2 (*f*) until two distinct layers are obtained.

(*g*) Place the vials in opposite slots of the potash rotator and rotate for exactly 30 seconds.

(*h*) Transfer the vials to the potash illuminator and, 30 seconds after stopping the rotator, make the turbidimetric readings by moving the slide back and forth over the lined chart and sighting downward through the column of the test liquid.

(*i*) Should the reading be two or less, repeat steps 2 (*c*) to 2 (*h*) using successively larger (by 0.1 ml.) aliquots of the extract, until all readings of 2 and 3 are obtained. Do not record a high 2 reading as a 3 reading. Do not record high 1 readings, but be sure to record high 3 readings. Eliminate extremes which cannot be duplicated consistently.

(*j*) Should the reading be 3, record this as such. Pipette 5 ml. of the extract into a clean, dry 50-ml. beaker and dilute it with 5 ml. of Reagent No. 1, K_2O. Mix thoroughly and repeat step 2 (*i*) with this diluted extract.

(*k*) Should the reading obtained in 2 (*j*) be 3 or greater, place another 5-ml. aliquot of the extract in a clean, dry 50-ml. beaker and dilute this with 10 ml. of Reagent No. 1, K_2O. Mix thoroughly and repeat step 2 (*i*).

(*l*) Refer to the data sheet for the value of the turbidimetric readings in terms of R.C.M. potash.

Note: Turbidimetric Potash x 3.5 gives Replaceable Potash.

3. To the set of soils in the 250-ml. beakers add 8 ml. of distilled water. Pipette 2 ml. of Potash Fixation Solution No. 1 into each beaker. Place a stirring rod in each beaker. Stir the soil well, and allow the stirring rods to remain throughout the ten drying processes.

(*a*) Heat the water bath to the maximum of the "low" heat of the hot plate. By adjusting the thickness of the insulating material between the bath and the plate surface, the water should be heated to a temperature of 72° C. Check this with the thermometer.

(*b*) Place the beakers containing the soil suspension on the screen of the water bath. Check the temperature of the suspension occasionally. Allow the soils to dry for one hour, or until friable.

(*c*) From the 250-ml. dispensing burette equipped with a 3-foot section of rubber tubing and a pinchcock, add 10 ml. of distilled water to each beaker, without removing it from the bath. Stir thoroughly, wetting any soil which may adhere to the sides of the containers.

(*d*) Repeat alternate wettings and dryings for a total of ten dryings. Should it be necessary to halt the procedure before ten dryings have been completed, do so at the end of an evaporation period. Do not add water again until the bath has had time to re-heat to temperature.

(*e*) Add 30 ml. of Reagent 1, K_2O to the soil after the tenth drying. Extract and determine the replaced potash by steps 2 (*b*) to 2 (*l*) inclusive.

4. Pounds per acre fixed is equal to the potash as determined in part 2 minus that as determined in part 3, multiplied by the factor 3.5.

5. Per cent fixation is equal to pounds per acre fixed multiplied by 100, and divided by pounds per acre as determined in part 2.

Should the amount of fixation be greater than 33 per cent repeat the entire procedure, using Potash Fixation Solution No. 2; 1 ml. of this solution applied to 5 grams of soil is equivalent to an application of potash at the rate of 4,900 pounds

per acre-foot, and will necessitate considerable dilution in making determinations by part 2 of the above procedure.

To adapt this procedure as outlined, for potash fixation studies under various fertilizer practices, use in addition to the potash fixation solutions, standard fertilizer solutions as prescribed on the labels of their containers.

Precautions:

It must be noted that variations in the temperature of evaporation, inaccurate measurement of the potash fixation solution added, and the improper reading of the turbidities in step 2 (*i*) may introduce considerable errors.

Reagents Used*

Reagent No. 1, K_2O:

An aqueous solution of sodium acetate, C.P., 500 grams in 8,000 ml. of distilled water. To 10,500 ml. of this solution are added 4,500 ml. of C.P. nitric acid in 1-1 solution.

Reagent No. 2, K_2O:

A solution of C.P. cobaltous nitrate, 318 grams and C.P. sodium nitrite, 1,200 grams in distilled water, 4,000 ml. containing 100 ml. of C.P. acetic acid. This reagent must remain for a time in storage in the dark, later is filtered, tested and shipped in small, amber glass-stoppered containers. It decomposes rather readily in the tropics and requires occasional inspection.

Reagent No. 3, K_2O:

Redistilled ethyl alcohol, exactly 95 per cent, containing the denaturants pyridine and xylol.

Potash Fixation Solution No. 1:

4.432 grams of C.P. potassium chloride dissolved in 1,000 ml. of distilled water.

Potash Fixation Solution No. 2:

15.530 grams of C.P. potassium chloride dissolved in 1,000 ml. of distilled water.

Additional fertilizer solutions used in the experimental work were:

Calcium Hydroxide:

Prepared as a 0.004 Normal solution by saturating 1,000 ml. of distilled, carbon dioxide free water with C.P. calcium oxide, and subsequently standardizing by titration. 16.1 ml. applied to 10 grams of soil are equivalent to an application of 6,000 pounds of the hydroxide per acre-foot.

Mono-calcium Phosphate:

Dissolve 1.775 grams of C.P. acid phosphate in distilled water and make up to 1,000 ml. 1 ml. applied to 10 grams of soil is equivalent to an application of 250 pounds of P_2O_5 per acre-foot.

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* Reagents No. 1, 2, 3, K_2O are described as given in *Soil and Plant Material Analyses by Rapid Chemical Methods*, The Hawaiian Planters' Record, 40, page 236, 1936.

The effect of non-potash fertilizers on fixation was determined by the following treatments:

Treatment A:

Potash applied as a solution of the chloride at the rate of 1,400 pounds per acre-foot of 2.5 million pounds weight, and immediately extracted and determined.

Treatment B:

Same as "A" except for artificial weathering prior to extraction and determination.

Treatment C:

Potash applied as in "A," and calcium as a solution of the hydroxide, at 6,000 pounds per acre-foot. The samples were weathered prior to extraction and analysis.

Treatment D:

Potash and lime were added as in "C." In addition, mono-calcium phosphate was added at the rate of 250 pounds per acre-foot.

TABLE II

PER CENT FIXATION OF POTASH APPLIED AT THE RATE OF 1,400 POUNDS PER ACRE-FOOT, AS INFLUENCED BY NON-POTASH FERTILIZERS

Soil	A	B	C	D
Kona	0.00	0.00	0.00	0.00
Olaa (uncultivated)	0.00	11.3	1.5	12.3
Olaa (cultivated)	0.00	4.7	6.4	3.9
Superior clay	0.00	43.8	52.0	49.7

It is obvious that material savings of potash may be realized by the proper control of potash fertilization of soils exhibiting a high degree of fixation of the nutrient.

Summary

The phenomena of potash fixation in difficultly available forms in some soils are of uncertain mechanism.

Some Hawaiian soils exhibit a tendency to fix potash in irreplaceable forms.

Fixation is increased in some soils under some conditions of fertilization. It may be reduced by proper fertilization control, by frequent and small potash applications, and by sub-surface fertilization.

Potash fixation studies may be conducted on plantations by means of an adaptation of the rapid chemical method for the determination of potash in soils, as devised by the Experiment Station, H.S.P.A.

Satisfactory accuracy may be maintained by using weighed soil samples and the method of cross checking turbidimetric values of various aliquots on the data sheet.

No correlation could be found between different temperatures of weathering and the resulting degrees of fixation.

A study of the availability of the fixed potassium to such long crops as sugar cane can be conducted only in field tests.

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Occurrence of the Minor Elements in Commercial Fertilizers as Determined Spectrographically

By Stanley S. Ballard

Introduction

In reviewing the pages of popular and of scientific literature the farmer is bound to find discussion, from time to time, warning him of the dangers of artificial fertilization where highly refined synthetic chemical compounds have been used as a substitute for the old standard natural products originating in stable refuse or in other animal, mineral or vegetable sources.

There can be no question as to the justification of this warning, for numerous studies have been described in the literature by workers in this field in which it has been shown that cropping in soils deficient in certain minor nutrients may not be restored to maximum or even to moderate yield by application only of relatively pure nitrogen, phosphoric acid and potash.

The so-called "less essential" elements play a very important role in plant nutrition. It is equally true that the more common elements function similarly, but they are necessary to the plants in much larger amounts. It is not an unusual practice to spray growing plants on a very large scale with a dilute solution of ferrous sulphate as a corrective for iron deficiency in those plants. Yet, the soil supporting the plants may consist largely of various forms of hydrated but difficultly soluble ferric oxide.

Therefore, solubility of required plant nutrient is an important factor. It is perhaps immaterial whether the nutrient remains soluble *after* application to the soil or whether it becomes soluble from an insoluble source by the action of the soil solution or of plant root systems. For instance, plant responses to exceedingly small applications to the soil of insoluble compounds of zinc, manganese and copper have been reported, while soluble sources of these same less common nutrients have been found equally effective. The difficultly soluble raw rock phosphate appears to be made available to plant life in either an acid or an alkaline soil medium.

Most fertilizer compounds in use today, whether synthetic or natural, are readily soluble. Many of them are endowed with a great variety of the minor elements. It should be of interest, therefore, to become acquainted with the extent and abundance of this nutrient endowment in present-day fertilizers as shown by Dr. Ballard in his brief but excellent summation of an extended program of spectrographic research on this subject. Francis E. Hance.

Discussion

It has been well known for some years that the ten most important elements to plant growth are carbon, hydrogen, oxygen, sulfur, nitrogen, phosphorus, potassium, calcium, magnesium, and iron. These elements are all essential to normal growth and must be available to the plant in fairly large amounts. Only the last six are ordinarily involved in fertilizer considerations. In recent years it has been shown

that in addition to the ten major elements there are certain other elements that are equally essential to normal growth, but are necessary in only small amounts. These are the so-called micro-metabolic, minor, less common, or "less essential" elements. Included in this group, for most plants, are manganese, boron, copper, zinc and perhaps aluminum and iodine. Then there are certain others whose importance to plants is at present being investigated, such as cobalt, nickel, tin, silicon and sodium. Certain other elements such as strontium and barium are often found to be present in plants, but are not known to perform any function therein.

Chemical fertilizer analyses, using either the standard or rapid chemical methods, may readily be made for the last six of the major elements listed above, and the spectrograph cannot compete here. The case of the minor elements is quite different, however. These elements are needed in such small amounts—only a few parts per million in the soil will often suffice—that their chemical determination is exceedingly laborious. They are ordinarily present in only small amounts in fertilizers also, and it is here that the sensitive and rapid semi-quantitative spectrographic method finds good application.

In this article there is reported the analysis of twelve commercial fertilizers commonly used in the Hawaiian sugar industry. The purpose was to secure a complete qualitative (or better, semi-quantitative) analysis of the materials for their mineral composition. Such an analysis reveals the presence or absence of about one-half of the ninety-two chemical elements, this list including all the metals and some of the metalloids. It therefore includes all the major and minor plant nutrients mentioned above except carbon, hydrogen, oxygen, nitrogen, sulfur and iodine. Of particular interest are the results for the minor elements. It is interesting also to note that certain fertilizers contain traces or small amounts of certain major elements other than the major nutrient constituent of the fertilizer. Also, since in the future other minor elements may be found to be essential to plant growth, it should be worth while to have on record the results of the *complete* analysis of the mineral composition of typical fertilizer materials.

Samples of the twelve commercial fertilizers were obtained from The Pacific Guano and Fertilizer Company of Honolulu. These are listed in Table I.

TABLE I

NAMES AND SOURCES OF THE TWELVE FERTILIZERS ANALYZED SPECTROGRAPHICALLY

Name	Source
Sulfate of ammonia	Trail, B. C. (Canada)
Sulfate of ammonia	Eastern U. S.; a by-product
Nitrate of soda	Hopewell, Va.
Nitrate of soda	Chile
Potash nitrate	Chile
Potash nitrate	Germany
Muriate of potash	Mojave Desert, California
Raw rock phosphate	Makatea (South Pacific)
Superphosphate	Made from Makatea rock
Raw rock phosphate	Florida
Superphosphate	Made from Florida rock
Ammo-Phos	American Cyanamid, Warners, N. J.

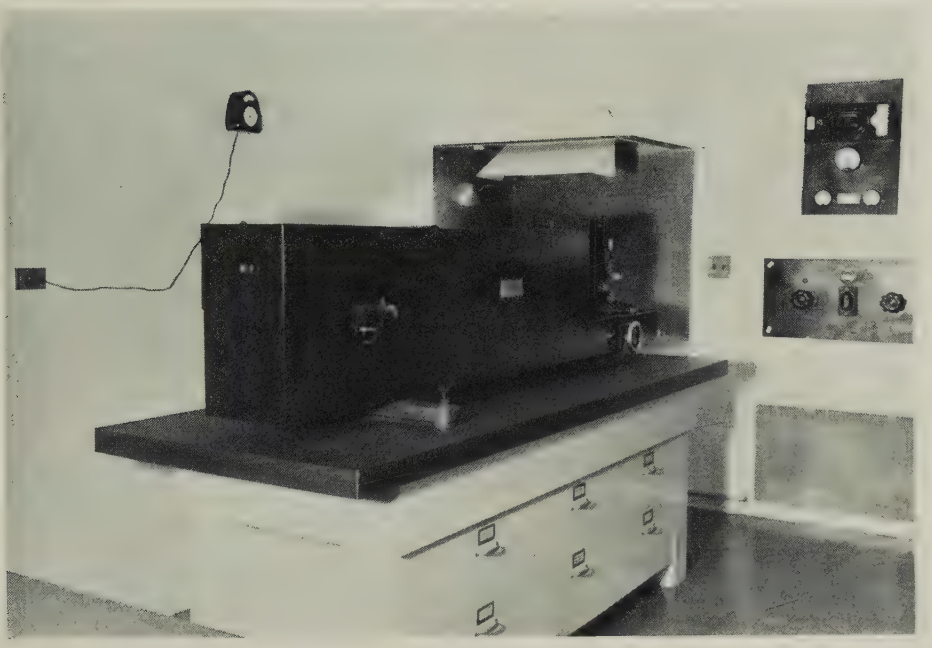

Fig. 1. The large quartz spectrograph. Note the hood over the far (plate-holder) end and the electrical control panel.

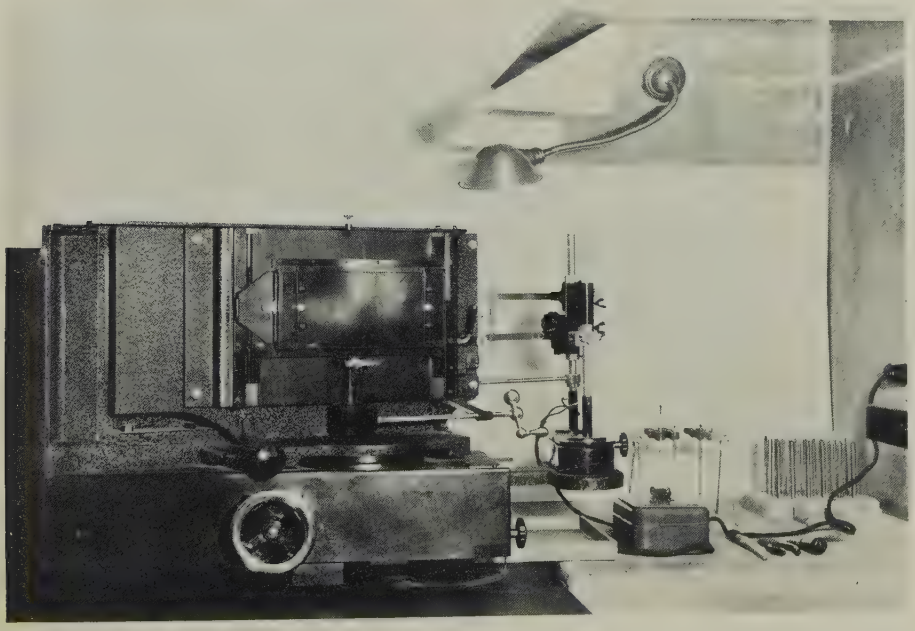

Fig. 2. Plate-holder end of spectrograph. The hood draws off fumes from the arc. Note the carbon arc, the rack with copper and iron electrodes, the prepared carbon electrodes (protected by inverted test tubes) and the reversing switch in the arc electrical supply line.

The technic used in obtaining the spectrograms was to incinerate weighed portions of the samples in copper and in carbon arcs and to photograph the light from the arc with the large quartz Littrow spectrograph shown in Figs. 1 and 2. The glowing arc stream is composed of atoms and ions of the constituents of the sample, as well as those of the electrode material. The spectrum of the light from the glowing arc therefore showed lines due to the various elemental constituents of the sample. Since the constituents of the electrodes were also registered, the purity of the electrode material was a matter of paramount importance. We used graphite and copper electrodes of the highest purity obtainable. The preparation of the electrodes was conducted with great care so that no impurities were introduced. A new method of introducing the samples into the arc which should avoid all contamination of the sample was devised and used. In all cases the spectrum of the bare electrodes was first photographed on the spectrum plate, this step being necessary in order to determine what impurities were present in the arc electrode material. In general the carbon electrodes were the freest from impurity, showing traces only of boron and silicon, while the copper electrodes showed impurities of tin, lead, nickel and iron. Arcing times of one minute sufficed for the complete incineration of the sample. The carbon arc current was maintained at 6.5 amperes and the copper arc current at 5 amperes. Voltage drops across the arc were 60-55 volts for the carbon arc and 40 volts for the copper arc.

For each fertilizer two plates were taken, one in our Range I which includes the visible part of the spectrum and one in Range II which lies entirely in the ultra violet. Thus this project involved taking twenty-four plates, two for each of the twelve samples. On each plate were photographed seven spectrum strips, one strip being the spectrum of the bare carbon electrodes, one of the carbon electrodes with a weighed portion of 10 mg. of the sample burning, one of the same electrodes with a large amount of sample, say 40-50 mg. burning, three copper exposures which were similar to the carbon exposures and a strip of iron spectrum. Lines in the rich spectrum of iron are always used as wave length comparison standards. The constitution of the various fertilizer samples could be compared in a quasi-quantitative fashion by referring to the spectrum strips of the equal weighed portions of 10 mg., while the spectra of the larger portions showed lines of the elements present in the smallest amounts. It might be mentioned that the arc currents used in this investigation, as well as the constant arc length of 4 mm., did not represent extreme exposure conditions. Fig. 3 is a reproduction of the Range I plate of Chile potash nitrate.

Since such small amounts of material were used in each analysis the method of sampling was of great importance. In order to obtain the small samples we first spread out the entire contents of the two-pound bottle on a piece of heavy paper and mixed it thoroughly. The material was then quartered repeatedly, small portions being drawn out until about 10 grams had been removed. The 10 grams of material were ground fine in a carefully cleaned agate mortar and were dried in a dust-proof electric oven. The 10- to 50-mg. samples of the pulverized fertilizer were then taken from this portion. We felt that these small samples represented as accurately as possible the material as we received it. We had no control, of course, over the original sampling of the fertilizers as they were received in Honolulu.

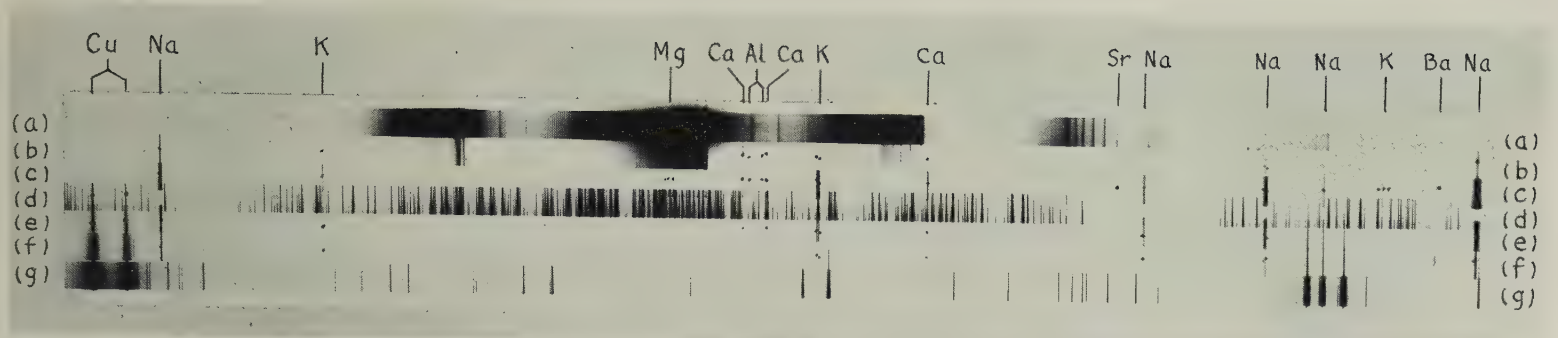

Fig. 3. Range I spectrogram of Chile potash nitrate fertilizer. Lines due to elements in the sample are dotted and their designations indicated. The seven strips are due to the following arc situations: (*a*) bare carbon electrodes; (*b*) carbon electrodes with 10 mg. of sample incinerated; (*c*) carbon electrodes with 40-50 mg. of sample incinerated; (*d*) iron electrodes, to give wavelength standards; (*e*) copper electrodes with 40-50 mg. of sample incinerated; (*f*) copper electrodes with 10 mg. of sample incinerated; (*g*) bare copper electrodes. The strips are photographed in the order (*a*), (*b*), (*c*), (*d*), (*g*), (*f*), (*e*). Note that the copper lines show in the last four strips but not in (*a*), (*b*) or (*c*). This shows that copper is an impurity of the iron electrodes, but does not occur in the carbon electrodes or in the sample. The heavily blackened areas in strips (*a*) and (*b*) are the cyanogen bands that are always produced by a carbon arc run in the air.

The Range II plate of Chile potash nitrate (not reproduced) shows that the sample contains iron as well as potassium, calcium, magnesium, aluminum, sodium, strontium and barium.

The collected results of the analyses of the twenty-four spectrum plates are given in Table III. Although this was essentially a qualitative method, some attempt was made to give semi-quantitative results. Thus, if the number and intensity of spectrum lines occurring on the plate indicated that the element concerned was present in a large amount in the sample, being perhaps a major constituent, we applied the designation "lots"; if the element was present in fairly large amounts, but was probably not a major constituent, we used the designation "some"; if the element appeared to be present in even smaller amounts, but still more than trace amounts, we used the designation "less"; if only the most sensitive lines of the element appeared on the spectrum plate a "trace" was reported. In order to give an even closer comparison between similar samples the added designations "plus" and "minus" were sometimes used, but such fine distinctions may not be significant in an analysis of this type. If the element was looked for, but not detected, it was specified as "N.D." in the table. If no designation was given, the element was not definitely looked for in the sample, probably because all the lines appearing on the spectrum plate had already been accounted for. These semi-quantitative designations are repeated in Table II.

TABLE II

SEMI-QUANTITATIVE DESIGNATIONS, ARRANGED IN THE ORDER OF DECREASING QUANTITY OF THE ELEMENT PRESENT IN THE SAMPLE

Lots
Some
Less
Trace
N. D. (not detected)

It should be stated that if an element was not detected it might still have been present in the sample, but in such very small quantities as to escape detection; in fact in certain borderline cases it was difficult to state whether a "trace" of the element was present or not. Minor fluctuations in the electrical conditions of the arc might be sufficient either to make the sensitive lines of the element barely visible or to subdue them in such cases. This effect was probably encountered in the case of boron, as discussed below.

TABLE III

COLLECTED RESULTS OF THE SPECTROGRAPHIC ANALYSIS OF TWELVE COMMERCIAL FERTILIZERS

Chemical element and symbol	Sulfate of ammonia (Canada)	Sulfate of ammonia (U. S.)	Nitrate of soda (Va.)	Nitrate of soda (Chile)	Potash nitrate (Chile)	Potash nitrate (Germany)	Muriate of potash (Calif.)	Raw rock phosphate (Makatea)	Super-phosphate (Makatea)	Raw rock phosphate (Florida)	Super-phosphate (Florida)	Ammo-Phos (N. J.)	Chemical element
Phosphorus, P	Trace	N.D.						Lots	Lots	Lots	Lots	Lots	Phosphorus
Potassium, K			N.D.	Trace	Lots	Lots	Lots	N.D.	N.D.	N.D.	N.D.	N.D.	Potassium
Calcium, Ca	Trace	Trace	Less—	Less	Less+	Some	Trace	Lots	Lots	Lots	Lots	Some—	Calcium
Magnesium, Mg	Trace	Trace	Trace	Less	Less	Less	Trace	Less+	Less	Less	Less	Less+	Magnesium
Iron, Fe	Less—	Less	N.D.	N.D.	Trace	Trace	N.D.	Some	Some	Some	Some	Some	Iron
Manganese, Mn								Less+	Less—	Less	Less	Some—	Manganese
Boron, B*								N.D.	N.D.	N.D.	N.D.	Trace	Boron*
Copper, Cu	N.D.	Trace	N.D.	N.D.	N.D.	N.D.	Trace	N.D.	Trace	Trace+	Trace—	Trace+	Copper
Zinc, Zn	N.D.	Trace						Trace	Trace	Trace	N.D.	N.D.	Zinc
Aluminum, Al	N.D.	Trace+	N.D.	Trace	Trace+	Trace+	N.D.	Some	Less	Less	Less+	Some	Aluminum
Nickel, Ni								N.D.	N.D.	Trace	Trace	Trace—	Nickel
Silicon, Si	Trace	Trace						N.D.	N.D.	Less	Less	Some	Silicon
Sodium, Na	Trace	Trace	Lots	Lots	Lots—	Less	Some—	Less	Less	Less	Less—	Less+	Sodium
Titanium, Ti								Trace	Trace	Trace	Trace	Trace—	Titanium
Lead, Pb	Trace	Trace						Trace	Trace	Trace	Trace	Trace	Lead
Chromium, Cr								Less	Less	Trace+	Trace+	Trace	Chromium
Strontium, Sr			N.D.	N.D.	Trace	Trace	N.D.	Trace+	Trace+	Trace+	Trace+	Trace	Strontium
Barium, Ba			N.D.	N.D.	Trace	N.D.	N.D.	N.D.	N.D.	Trace—	Trace—	N.D.	Barium
Vanadium, V								N.D.	N.D.	Trace	N.D.	Trace	Vanadium
Molybdenum, Mo								N.D.	N.D.	N.D.	N.D.	Trace	Molybdenum
Fluorine, F								Less+	Less+	Less	Less	N.D.	Fluorine

* See discussion in text regarding low sensitivity of boron detection.

There is also the factor that the various elements differ considerably in their arc sensitivity. For instance, sodium detection by a certain spectrographic technic may be a thousand times more sensitive than phosphorus detection. For this reason it is important to know the relative arc sensitivity of the various elements commonly encountered in agricultural work. In Table IV are given the approximate lower limits of detection of the elements encountered in this investigation. The absolute amounts quoted apply only to the technic used and are at best only very approximate.*

TABLE IV

TABLE SHOWING APPROXIMATE SMALLEST AMOUNTS OF THE VARIOUS ELEMENTS DETECTABLE SPECTROGRAPHICALLY

Per cent	Parts per million	Elements
.0001 – .001	1 – 10	Magnesium, copper, nickel, sodium, chromium
.001 – .01	10 – 100	Calcium, iron, manganese, aluminum, titanium, lead, strontium, barium, vanadium, molybdenum
.01 – .1	100 – 1000	Boron, zinc, silicon
.1 – 1.0	1000 – 10,000	Phosphorus, potassium

The apparent insensitivity of potassium to spectrographic determination, with a lower limit of around one-tenth of one per cent, is due to the fact that the most sensitive lines of potassium lie at the far red limit of the visible spectrum, outside our standard ranges. We propose to establish a standard range in the far red so that small concentrations—say 10 parts per million—of potassium can be detected. Other elements whose sensitive lines lie in this region are lithium, rubidium and cesium. Boron, zinc and silicon are also relatively insensitive, only 0.01 to 0.1 per cent being detectable spectrographically by the technic used in the present investigation. However, we now have available a stronger, more searching technic which involves the use of higher arc currents and shorter arc lengths and which increases the sensitivity of boron and zinc detection, as well as that of the other arc-sensitive elements, perhaps a hundredfold. The sensitive lines of arsenic and beryllium lie even deeper in the ultra violet than our Range II, so that these two elements could not be analyzed for in the present investigation. Since this work was done, however, we have established a special range which includes the sensitive lines of arsenic and beryllium and in which we can reach a lower limit of about 20 parts per million in arsenic detection in soils.

Due to the important effect upon the behavior of the arc of the identity of the major constituents of a sample, comparisons of relative amounts of impurities in samples of different major composition must be made with extreme caution. For this reason the various fertilizers listed in Table III will be discussed in groups, each group being arranged so that all its members will have approximately similar major constitution and will hence be readily comparable.

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* These data are adapted from the work of Ryde and Jenkins of the General Electric Co. Research Laboratories (England). *Wavelength Tables for Spectrum Analysis*, p. 130, 2nd Ed. 1931, Adam Hilger, Ltd., London.

TABLE V

AMMONIUM SULFATE FERTILIZERS

Chemical element and symbol	Sulfate of ammonia (Canada)	Sulfate of ammonia (U. S.)
Phosphorus, P	Trace	N.D.
Calcium, Ca	Trace	Trace
Magnesium, Mg	Trace	Trace
Iron, Fe	Less—	Less
Copper, Cu	N.D.	Trace
Zinc, Zn	N.D.	Trace
Aluminum, Al	N.D.	Trace+
Silicon, Si	Trace	Trace
Sodium, Na	Trace	Trace
Lead, Pb	Trace	Trace

Table V gives the results of the analysis of two fertilizers whose major constituent was ammonium sulfate. In the case of these two samples, *every* unknown line on the spectrum plates was accounted for and so a complete analysis of the fertilizers for the fifty-odd arc-sensitive elements was made. An inspection of the table reveals that the U. S. sulfate of ammonia sample contained more iron than the Canadian sample and contained traces of copper, zinc and aluminum. The Canadian sample, on the other hand, contained a trace of phosphorus. In general it is seen that the ammonium sulfate fertilizers contained relatively few impurities and that all of these occurred in very small amounts.

TABLE VI

FERTILIZERS CONTAINING A LARGE AMOUNT OF AN ALKALI METAL (SODIUM OR POTASSIUM)

Chemical element and symbol	Nitrate of soda (Va.)	Nitrate of soda (Chile)	Potash nitrate (Chile)	Potash nitrate (Germany)	Muriate of potash (Calif.)
Potassium, K	N.D.	Trace*	Lots	Lots	Lots
Calcium, Ca	Less—	Less	Less+	Some	Trace
Magnesium, Mg	Trace	Less	Less	Less	Trace
Iron, Fe	N.D.	N.D.	Trace	Trace	N.D.
Copper, Cu	N.D.	N.D.	N.D.	N.D.	Trace
Aluminum, Al	N.D.	Trace	Trace+	Trace+	N.D.
Sodium, Na	Lots	Lots	Lots—	Less	Some—
Strontium, Sr	N.D.	N.D.	Trace	Trace	N.D.
Barium, Ba	N.D.	N.D.	Trace	N.D.	N.D.

* See discussion in text regarding low sensitivity of potassium detection.

In Table VI are repeated the analytical results for the five fertilizers that contained a large amount of an alkali metal (either sodium or potassium). It is well known that a large amount of an alkali metal dominates arc conditions to such an extent that the weak lines of "trace" elements are depressed in intensity or may actually be subdued entirely. For this reason it should be stated that the rather high purity of these samples is doubtless more apparent than real. Again, all the lines on the ten spectrum plates were accounted for.

TABLE VII

FERTILIZERS CONTAINING A LARGE AMOUNT OF AN ALKALINE EARTH (CALCIUM)

Chemical element and symbol	Raw rock phosphate (Makatea)	Super-phosphate (Makatea)	Raw rock phosphate (Florida)	Super-phosphate (Florida)	Ammo-Phos (N. J.)
Phosphorus, P	Lots	Lots	Lots	Lots	Lots
Potassium, K	N.D.	N.D.	N.D.	N.D.	N.D.
Calcium, Ca	Lots	Lots	Lots	Lots	Some—
Magnesium, Mg	Less+	Less	Less	Less	Less+
Iron, Fe	Some	Some	Some	Some	Some
Manganese, Mn	Less+	Less—	Less	Less	Some—
Boron, B	N.D.	N.D.	N.D.	N.D.	Trace
Copper, Cu	N.D.	Trace	Trace+	Trace—	Trace+
Zinc, Zn	Trace	Trace	Trace	N.D.	N.D.
Aluminum, Al	Some	Less	Less	Less+	Some
Nickel, Ni	N.D.	N.D.	Trace	Trace	Trace—
Silicon, Si	N.D.	N.D.	Less	Less	Some
Sodium, Na	Less	Less	Less	Less—	Less+
Titanium, Ti	Trace	Trace	Trace	Trace	Trace—
Lead, Pb	Trace	Trace	Trace	Trace	Trace
Chromium, Cr	Less	Less	Trace+	Trace+	Trace
Strontium, Sr	Trace+	Trace+	Trace+	Trace+	Trace
Barium, Ba	N.D.	N.D.	Trace—	Trace—	N.D.
Vanadium, V	N.D.	N.D.	Trace	N.D.	Trace
Molybdenum, Mo	N.D.	N.D.	N.D.	N.D.	Trace
Fluorine, F	Less+	Less+	Less	Less	N.D.

In Table VII are repeated the results of the analysis of the four fertilizers whose major constituent was calcium phosphate. Here the dominating element in the arc was doubtless calcium, and since the Ammo-Phos sample was found to contain a rather large amount of calcium the results of its analysis are included in this table. It should be stated, however, that a close comparison of Ammo-Phos with the other four samples would not be as reliable as comparisons between these four. In the case of these five samples the spectra were very complicated, due to the large number of elements present and particularly to the considerable amount of iron, with its many-lined spectrum. For this reason, rather than accounting for each one of the hundreds of lines occurring on each of the ten spectrum plates, each plate was examined for the presence or absence of all elements whose presence one had any reason to suspect. In addition to the twenty-one elements reported in Table VII and in Table III, the following were looked for but not detected in each of these samples: Cobalt, tin, silver, cadmium, bismuth, antimony, thallium, zirconium and germanium. Lithium, rubidium, cesium and beryllium were also looked for and not detected, but, as discussed above, their most sensitive lines lie outside the range covered by the spectrum plates. In some cases, namely Chile potash nitrate, muriate of potash, Canadian sulfate of ammonia and the Florida rock samples, "trace" lines of boron seemed almost to be indicated, but boron could not be reported with certainty. Repeating the plates with the new stronger technic mentioned above would readily show boron lines, if indeed boron was present in appreciable amount. This has not been done since boron does not appear to be a problem in Hawaiian agriculture at present.

Table VII shows that the last five fertilizers are the best sources of the minor elements. The comparison between the Makatea and Florida samples shows that the Makatea rock and superphosphate seem to have more chromium and fluorine while the Florida samples show traces of nickel, silicon and barium. The fact that copper showed as a "trace" in Makatea superphosphate while it was not detected in Makatea raw rock phosphate should not be given too much significance in view of the borderline nature of the "trace" designation discussed above. This also applies to zinc and vanadium in the Florida samples. In general, the metallic constitution of the rock phosphate and superphosphate fertilizers would seem to be as follows: "lots" of phosphorus and calcium, "some" iron, "less" magnesium, manganese, aluminum, sodium and possibly chromium and fluorine, and "traces" of copper, zinc, titanium, lead and strontium.

Thanks are due Paul E. Chu, Assistant Chemist, for his most valuable assistance in preparing the samples and in securing the twenty-four spectrograms. Grateful acknowledgment is made to R. Q. Smith of The Pacific Guano & Fertilizer Company for his helpful criticism of the manuscript.

Selenium—I

A general discussion based upon the properties of the element, its absorption by plants and its effects upon horses, cattle and hogs as transmitted through forage

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By Francis E. Hance

The element selenium occurs in the surface crust of the world in amounts calculated to equal that of silver. It has been found in meteors. Byers, Williams and Lakin (1) have published a discussion, with data, on its occurrence in Hawaii.

Interest in the natural presence of the element in farm and ranch lands is concerned principally with its purported property of adversely affecting grazing and other stock which are fed vegetation grown on seleniferous soils.

Selenium appears to be one of nature's outstanding elemental substances in the latitude of its properties, in the multiplicity of its uses and in the abnormal and frequently serious effects it may produce in certain animals when it enters their systems in food.

Selenium is indispensable to the rubber, electrical and glass industries. It is remarkably sensitive to light, so much so that by its employment light may be converted into electrical energy. When used with a suitable relay, a selenium light-sensitive cell may start and stop motors, ring or silence bells, light or extinguish lamps, protect safes, fire a cannon at a distance or function in many other operations, directly or by remote control. Selenium imparts to rubber a property which makes it resistant to abrasion, high temperature or even combustion. Hence, it is valuable and is used in automobile tire casings and inner tubes. Selenium rubber is used in insulating electrical cables which must withstand heat and continual movement over hard, rough surfaces. Selenium imparts a terra cotta red to rubber and a brilliant permanent scarlet to glass, enamelware and pottery. Diethyl selenide has been used as a satisfactory substitute for lead tetraethyl in anti-knock motor fuel. Colloidal selenium has the properties of a germicide, insecticide and fungicide.

One of its compounds, selenium oxychloride, approaches to a remarkable extent many of the desirable characteristics of the "universal" solvent long sought by ancient and, in a lesser degree, modern chemists.

The research chemist devoting his time in the laboratory to the study of selenium is a man apart from his fellows. His breath, perspiration and body carry odors of the foulest nature. This odor has been described as suggesting horseradish, garlic and brass, all combined. Commenting on selenium odors in man, a writer (5) in a publication by Arthur D. Little makes this statement: "The skunk might have a research job done by the chemist, using selenium, to *increase* his 'Schrecklichkeit'" *(frightfulness)*.

In cereals, grasses and other vegetation, selenium may or may not give warning of its presence by imparting garlic-like odors. Such vegetation may prove swiftly or lingeringly fatal to animals which eat it. Frequent references are made in the literature to articles describing diseases and suffering in animals poisoned by eating forage contaminated with selenium.

Fig. 1. This photograph shows the loss of the long hair from the tail after the horse had been on an affected ranch for only six weeks.

Fig 2. Cross section of a hoof from an "alkalied" horse. The arrows indicate points at which growth has been interrupted.

The toxicity to humans of food containing selenium does not appear to have been established, although Thorp (12), from soil studies made in China, expressed the belief that the symptoms of osteomalacia (softening of and deformities in bones) in humans may be due to selenium rather than to a deficiency of calcium or phosphorus in the soils.

Hurd-Karrer (3) states that it is not known whether man is susceptible to ills attendant upon a diet containing selenium. She adds that probably the danger is slight, particularly so in non-affected areas, because the normal human diet is so diverse.

In a field study made during 1936 upon a selected group of 50 rural families in a highly seleniferous soil area in four counties of South Dakota and Nebraska, Smith and Westfall (11) examined 100 urine specimens from 100 individuals and also the locally produced foodstuffs which constituted the principal diet of these people. They found that other than a high incidence of symptoms suggesting impaired functioning of the intestinal tract and a few cases of apparent hepatic dysfunction, no other evidence of ill health was seen that could be ascribed to selenium with any degree of certainty. The disorders found were believed due *probably* to continual selenium ingestion.

Commenting on the urine analysis field study made upon the South Dakota and Nebraska families discussed above, a writer (9) in the Pacific Rural Press makes this observation: " . . . human beings use as much as needed of such things as lead, arsenic, fluorine and selenium, establishing a useful balance, and excreting the remainder." This statement apparently is an opinion for no data are cited. It has been shown by Moxon and others that the organs of elimination and excretion, certainly in animals, are damaged by the poisonous effects of ingested selenium.

There appears to exist a very low level requirement in humans for many of the rare and even *poisonous elements. A statement in a text* by Mellor (6) credits T. Gassmann with finding selenium a constant constituent of teeth and bones. Gassmann stated that healthy teeth contain about 0.056 per cent of selenium (560 parts per million) and even in cases of diseased conditions of the teeth the same general figure prevails. Urine, he states, contains 0.0011 per cent of selenium in male and 0.0009 per cent in female persons. Vegetables also contain selenium, especially spinach. On the other hand, Mellor refers to another article by R. Fritsch in which the latter denies the presence of selenium in urine or in bones.

The finding by Gassmann regarding selenium in teeth does not appear to be questioned. To check on this point, however, the author and associate obtained several hundred specimens of extracted teeth from Honolulu dentists. In a thorough analytical study by E. K. Hamamura in this laboratory these teeth were found to be absolutely devoid of any suggestion or trace of selenium.

Colloidal selenium was found to give encouraging results in an investigation by Flury (2) in the treatment of hydrocyanic acid poisoning.

The human organism may or may not have a tolerant reaction to selenium occurring in foods. Data published on this point are not sufficient to justify either conclusion, for or against its toxicity to humans.

In a like manner the presence of the element selenium in soil does not appear to seriously retard the normal growth of many plants and grasses. In fact, it seems

Fig. 3. This photograph shows the separation of the hoof from the foot of a horse which died after it had been on an affected ranch for only eight weeks.

Fig. 4. Photograph showing the separation of the hoof from the foot of a 14-day-old colt. The colt was born with its feet in this condition.

that certain plants thrive on seleniferous soils and, moreover, the appearance of these plants in any given district may *indicate* the occurrence of selenium in the soil supporting them. Miller and Byers (7) have classified plants according to their tolerance for selenium in soil. Dividing such plants into 3 groups, they place in Group No. 1 plants that absorb selenium readily and which may be classed as the "indicator" type mentioned above. In Group No. 2 they place wheat, barley, rye and corn because of the fact that these cereals are able to absorb moderate or even large quantities of selenium without thereby suffering injury themselves. A third grouping is reserved for buffalo and grama grasses which, they state, have a very limited tolerance for selenium and are able to absorb only small quantities when grown on seleniferous soils.

Moxon (8) describes another class, which he terms "converter" plants. This class, typified by *Astragalus bisulcatus* and *A. pectinatus,* has the apparent ability of absorbing insoluble selenium from the soil and converting it into a semi-organic soluble form in the plant tissues. After maturing, dying and falling back on the soil, the decayed plant will leave its soluble selenium in a form which is available to wheat and other crop plants. He quotes similar observations by other investigators which support this premise.

Knight and Beath (4) report that seleniferous Wyoming shale, originally non-toxic, was converted to a toxic condition in three years by growing from seed some of the native seleniferous weeds *in situ.*

It is evident, therefore, that plant selectivity exists for selenium in soil. Also, that specific kinds of plants will absorb selenium from insoluble inorganic sources in the soil and in some cases actually build up or concentrate this absorbed selenium in a soluble, semi-organic form. Other plants growing in the same locality may ignore or reject the insoluble fraction of soil selenium. However, when the "converter" plants return their soluble selenium to the soil in an available form, then *any* growing vegetation may take it up and perpetuate the cycle of selenium conversion.

These facts established, a discussion will be presented on the observed effects of selenium, when present in forage vegetation and grain, upon mainland animals and poultry which consume it in food. It is this phase of the subject which commands our principal interest in Hawaii, for symptoms of selenium poisoning in animals have been observed here and the presence of the element in Hawaiian soils has been reported by Beyers et al (1) and found by ourselves.

As pointed out by Moxon (8), the first recorded reference, perhaps, to alkali (selenium) disease may be found in the writings of Marco Polo, the Venetian, descriptive of his travels in China in the 13th Century. Referring to the revision of Marsden's translation of the Travels of Marco Polo (10), it develops that upon reaching the district of Succuir in the general Province of Tanguth, Marco Polo noted that a most excellent kind of rhubarb was grown in a mountainous district there and sent to all parts of the world. He also wrote that to venture in this district with any beasts of burden, excepting those accustomed to the country, was to invite disaster. He observed that a certain poisonous plant indigenous to the locality, if eaten by the animals, had the effect of causing their hoofs to fall off.

Fig. 5. Fore feet of a severely "alkalied" cow.

Fig. 6. Hind feet of a severely "alkalied" cow.

He adds that, "Those of the country, however, being aware of its (the weed's) dangerous quality, take care to avoid it."

In a footnote the editor refers to a publication, *Ruins of Desert Cathay,* by Sir Aurel Stein, in which the latter mentions the wild rhubarb and also describes difficulties with his ponies due to poisonous forage in this region.

Trelease and Martin (13) state that there appears to be some variation in the selenium poisoning of livestock, depending upon the type of plant which has been consumed. They suggest that different plants may carry the poison in a number of variable chemical combinations and that, in some cases, other toxic substances may be present which may accentuate or perhaps supplement the injury actually caused by selenium. They mention that Draize and Beath distinguish two types of the disease in livestock, namely, "alkali disease" and "blind staggers." Alkali disease is a misnomer, the term originating years ago as a result of the belief at that time that the disease was caused by the "alkali" waters of the affected localities. Trelease and Martin (13) describe alkali disease as the milder form of selenium poisoning, a malady characterized by deformation and loss of hoofs and by a loss of hair. Blind staggers is the acute form of the disease. It is usually fatal to livestock and does not produce the hoof and hair symptoms of the milder form of the disorder. With both diseases, however, they state that injury to the liver of the animal is similar.

Moxon (8) states that, in general, alkali disease (chronic selenium poisoning) may appear in animals when their feed contains as little as from 5 to 40 parts of selenium in a million parts of feed. Symptoms of the disease may be observed a few days or weeks after the animal starts feeding regularly on the selenized diet. He adds that many ranchers have expressed the belief that by grazing for only one night in a seleniferous pasture or by eating one feeding of seleniferous grain horses may lose the hair from their manes and tails and, in some cases, they may lose their hoofs or become so lame that they can walk only with difficulty. Blind staggers, he states, is the acute form of the disease. Paradoxically, an animal suffering from blind staggers does not necessarily become blind nor does it invariably stagger about. In summarizing Draize and Beath's description of blind staggers, Moxon writes that in the early stages of the illness cattle tend to stray from the herd. There is a slight impairment of vision which interferes with the animal's judgment of distances of objects in its path. In the next stage vision becomes more impaired, the animal attempting to push solid objects to one side rather than go around them. Appetite becomes depraved with a desire to chew wood, bone and metallic objects. Final stages of the disease are characterized by paralysis, grating of teeth, salivation and grunting. The animal shows evidences of abdominal pain; death usually follows from failure of respiration.

Symptoms in animals similar to those described by Moxon for the chronic or milder form of the disease have been observed in Hawaii. Moxon states that dullness and lack of vitality are general symptoms and that the animals become emaciated, their coats become rough and their desire for food becomes less and less, even when moved to a non-seleniferous area. In advanced cases of this milder form of selenium disease, the heart and liver of the animals become severely damaged. Moxon mentions that cases of atrophy of the heart (dishrag heart) and atrophy and

Fig. 7. Photograph of "alkalied" cow's head showing a ring on the horn which marks an interruption in the growth of the horny material similar to the interruptions in growth of hoof in Fig. 2.

Fig. 8. A grazing scene showing an "alkalied" steer which has assumed a kneeling position, while grazing, to avoid standing on its fore feet which were badly diseased.

cirrhosis of the liver have been found in animals afflicted with the disease. Anemia is a common symptom; likewise erosion of the bones, especially the joints of the long bones, the animal's gait becoming stiff and halting. Moxon points out that the bone injury is accompanied by a disturbance of the calcium-phosphorus metabolism. It is of interest to note again that Thorp (12), in his discussion of soil studies made in China, suggested that a bone malady prevalent there in humans may have been due to selenium rather than to a deficiency of calcium and phosphorus in the soil.

Horses, cattle, hogs and poultry are susceptible to selenium poisoning.

A. L. Moxon's description of the symptoms of the disease in each class of animals is given below. Mr. Moxon has very kindly forwarded the cuts used to illustrate the symptoms of selenium diseases in affected animals which came under his observations. With his permission these illustrations are repeated here for the benefit of Hawaiian readers.

Horses:

First symptoms are loss of hair from tail and mane, followed by soreness of feet. A ring begins to show on the upper border of the wall of the hoof (coronary cushion). In severe cases the hoof may become partially separated at the line of the ring with new growth starting at this point. During the shedding period the animal is in pain and often will not move. Unless watered and fed, it will die of starvation. Colts born of selenized parents may have deformed hoofs and show other symptoms of the disease.

Severe or acute injury to horses by selenium poisoning occurs only in districts where deposits of selenium in the soil are comparatively high or where "converter" plants have been growing for some time. These symptoms have been described previously.

Cattle:

Early symptoms of the disease in cattle are lameness and loss of hair from switch. Hoof injury is similar to that described as occurring with horses. Animals will occasionally rest on their knees when grazing because of pain in the fore feet experienced in standing. Usually the old hoof does not shed completely but remains attached to the new growth. Cattle have been known to grow ragged hoofs extending eight to ten inches upward at the extremities. The horns of cattle will sometimes show ridges or rings comparable to the hoof injury. Their legs may become stiff due to bone erosion. Even in very mild cases of poisoning, where no hoof or horn injury is apparent, the animal may become emaciated and lose weight. Extreme emaciation (off feed and loss of weight) is common in more severe cases of the disease. Young calves may show common symptoms of the disease when born or the disease may develop during nursing. The milk from diseased cows may contain considerable quantities of selenium.

Hogs:

When fed selenized ration, hogs may become lame. Loss of hair, generally from the entire body, is quite common. In some cases hoof growth becomes irregular and shedding of hoofs occurs very much as in the cases of diseased cattle and horses.

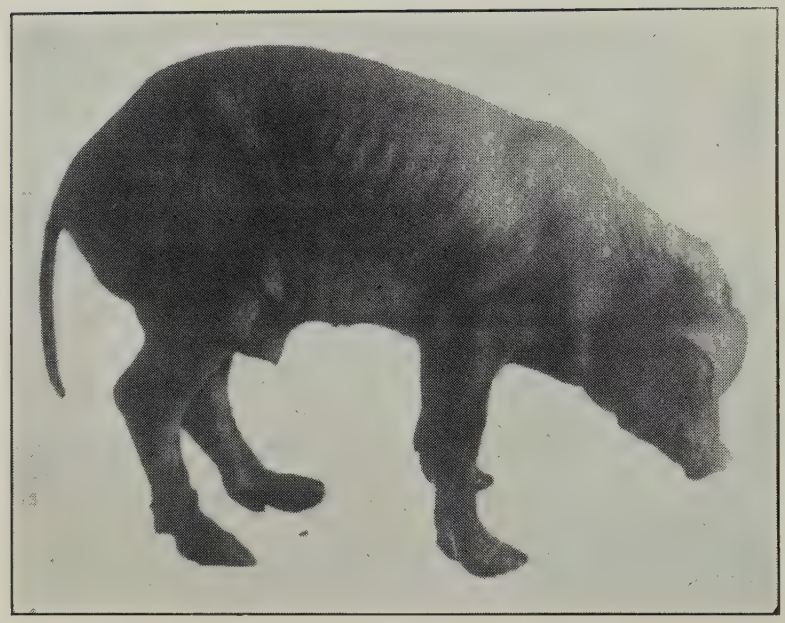

Fig. 9. An "alkalied" pig. Notice the general run down condition, thinness of hair, and diseased feet.

Fig. 10. Day-old chick, hatched from an egg laid by a hen which was fed seleniferous grains. Notice the weak condition and wiry down.

Suckling pigs may be affected by the selenium transmitted from the mother in her milk.

Poultry:

Most damage to chickens by selenium poisoning appears to originate in the immediate progeny and to be manifested at hatching. For instance, hens may be fed grain grown on selenium soils without showing any ill effects whatever. Their eggs may be fertile, but are likely not to hatch well. On the other hand, they may hatch in a satisfactory manner but may produce deformed chicks with wiry down. Monstrosities are also hatched at times, having hideous deformations. The poultry phase of selenium poisoning has been given attention and study by several mainland research groups. Due to the belief that Hawaiian poultry has not been affected by the disease, no further discussion of this subject will be offered.

Leucaena glauca (koa haole), a common nitrogenous Hawaiian plant acceptable to grazing stock, has been found by Mr. Hamamura in this laboratory to carry a higher percentage of selenium (1.4 p.p.m.) than a soil (0.25 p.p.m.) upon which the plant was growing. Other specimens of the same plant collected from non-seleniferous districts have been found to be free from selenium.

Observations are common in Hawaii on loss of mane and tail in mules and horses and complete loss of hair in hogs which have been fed *Leucaena glauca* from certain districts. An investigation is now in progress, the object of which is to obtain specific information on this point in connection with the presence or absence of selenium in soils and associated plants, a factor which may have contributed to the cause of disorder in these animals. The investigation will include a general survey of Hawaiian soils including prevailing local vegetation as suggested by Byers, et al (1). L. R. Smith, Associate Agriculturist, E. L. Caum, Associate Botanist, and Mr. Hamamura, Assistant Chemist, have agreed to cooperate with the author in this study. The findings will be presented in a future issue of the *Record*.

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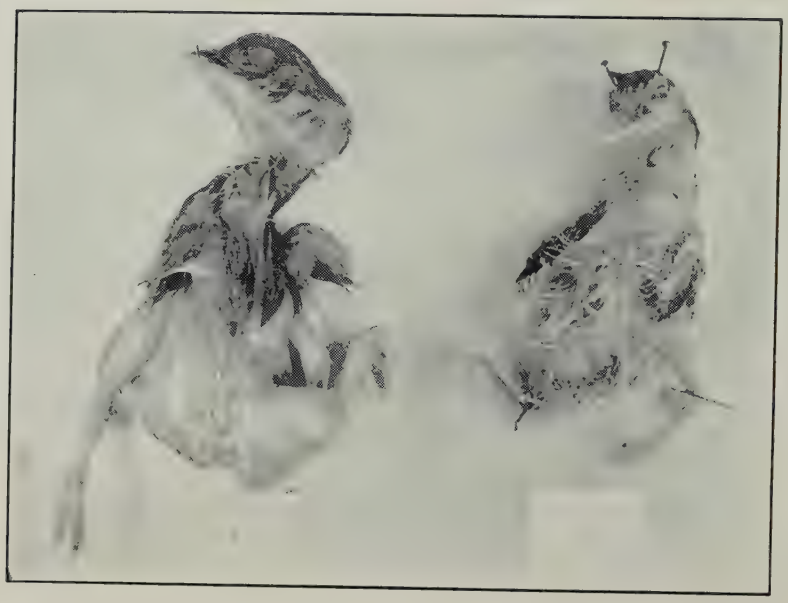

Fig. 11. Two chicks which were alive (in the shells) on the twenty-third day.

Fig. 12. A typical deformed chick. Notice the eye, beak and foot deformities and the absence of wings.

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Fig. 13. "Alkalied" chick, eyes and upper beak missing, feet deformed.

Fig. 14. "Alkalied" chick from series 3.

Fig. 15. Deformed embryo resulting from the injection of .01 p.p.m. of selenium into the air cell of a fertile egg before incubation.

Some Insect and Other Animal Pests in Hawaii Not Under Satisfactory Biological Control

By C. E. Pemberton and F. X. Williams

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Introduction

Although a number of insect pests in the Hawaiian Islands have been brought under excellent control by biological methods, many others, and a few that are not insects, still occur which seriously damage plants of agricultural or ornamental value. Little attention has been given to their control by parasites, predators, diseases, etc., and it is probable that in some cases at least, the damage could be permanently checked by utilizing natural enemies which may be found in other parts of the world. In some cases parasites and predators, not already in Hawaii, are known. These should be introduced. In others it is quite possible that careful investigation would reveal control factors, unknown at present, which could be transported to Hawaii. Few within the Islands are aware of the entomological problems of economic importance that still require solution within the Territory. The object of the present paper is to summarize this information, in brief form, and offer suggestions, wherever possible, to serve as a guide to entomologists who may have opportunity to investigate any of these problems in the future. Most of the prominent plant pests which have few or no natural enemies of importance in Hawaii are included. The home, if known, the host plants, damage and known parasites and predators elsewhere, are given whenever possible.

Common Garden Snail

Eulota similaris (Férussac)

Adventitious in Hawaii. It occurs also in Eastern Asia, East Indies, Japan, South America and West Indies. There are many Asiatic species of *Eulota*. It is a flower and vegetable garden pest.

The larvae of species of lampyrid beetles feed upon various helicine snails. For *Lampyris noctiluca* of Europe, see Newport (73) and Fabre (22). A Philippine species was noted by Williams (120, pp. 102-103) feeding upon a snail that somewhat resembled a species of *Eulota*. In Europe and North Africa, the larvae of drilid beetles destroy many helicine snails, Mielzinsky (70), Crawshay (16), and Rosenberg (83). In Europe and North America, carabid beetles of the group Cychrinae prey upon helicine snails. The European calliphorid fly *Melinda cognata* feeds as a larva in living terrestrial snails, Schmitz (85), Keilin (55). For further information and summary see Bequaert (8).

Sugar Cane Stalk Mite or Cane Rust Mite

Tarsonemus spinipes Hirst

For some time confused here with the rather similar *Tarsonemus bancrofti* Michael, the Java sugar cane stalk mite, Pemberton (75).

Spinipes occurs in the West Indies, Peru, and the Hawaiian Islands.

The damage to sugar cane is most characteristic in the eye groove, the mite causing small reddening blisters on the surface of the young internodes while still ensheathed. This mite is suspected of causing galls on cane stems, Pemberton (76). Other species of the genus cause galls on plants. The eggs have been described by Carpenter (14).

There appear to be no known specific enemies of this mite, but the damage is generally not sufficient to warrant costly remedies.

Black Widow Spider

Latrodectus mactans (Fabricius)

This is an American species favoring warmer climates. It occurs nearly everywhere in the United States, and ranges from Canada to Tierra del Fuego, Baerg (3). An immigrant to Hawaii where it was first reported by Hadden (39) in 1925. Now it is widespread in the more arid lowlands of the Archipelago. The female is the more venomous; its bite found to be occasionally fatal to man on the U. S. A mainland. One female often lays 1000 or more eggs, distributed in several cocoons.

Enemies: In Corsica, Ferton (25, pp. 164-165) noted the pompilid wasp, *Pompilus rytiphorus,* preying on the venomous *Latrodectes 13-guttatus.* The American blue mud-daubing wasp, *Chalybion caeruleum* (Linn.), a spider catcher and a recent immigrant in Hawaii, may store a goodly proportion of *Latrodectus mactans* spiders, Irving and Hinman (52). Pemberton (77) has found these spiders stored in the mud nests of *Sceliphron caementarium* (Drury) in Hawaii. It is possible that *Chalybion* wasps used the empty nests of *Sceliphron* for storing its spider prey, which is the usual habit of the former. Herms, Bailey, and McIvor in California (45) give a good account of *Latrodectus mactans* and of two of its parasites that feed within its egg cocoons; one of these parasites is a small chloropid fly, the other a braconid wasp of the genus *Gelis.* Jenks (53) gives a good illustrated account of the parasitic chloropid fly—known as *Gaurax araneae* Coq.—a California insect.

For a local account of the Black Widow see Illingworth (49). Dr. Nils P. Larsen (65) in Hawaii experimented on guinea pigs with the venom of the black widow. An effective remedy against the bite of the black widow is the intravenous administration of magnesium sulphate—see Frawley and Ginsburg (28). There are many other important references on the Black Widow.

Garden Centipede

Scutigerella immaculata (Newport)

The so-called garden centipede, *Scutigerella immaculata,* is not a true centipede but "a centipede-like animal belonging to the class Symphyla, members of which are considered by some students as possibly ancestral to both insects (Class Insecta) and true centipedes (Class Chilopoda)" (121). It has been known in Hawaii for many years, but its correct identity was not established until November 1, 1928 (48). There is no evidence to indicate when or how it first reached Hawaii. It has a world-wide distribution. The original home is unknown.

This symphylid seriously damages young pineapple plants in restricted soil area in Hawaii by eating out the growing root tips. The damage is often sufficient to almost kill the plants. Illingworth (47) has discussed this damage and the habits of the pest in detail. According to Wymore (121) it sometimes destroys large areas of asparagus in California unless expensive control measures are resorted to. The soft-bodied, pure white garden centipede is about ¼ inch long when mature. The 12 pairs of legs readily distinguish it from true centipedes.

No important natural enemies have been reported. Illingworth (47) has noted a staphylinid beetle *Philonthus discoideus* and a cucujid beetle *Cryptamorpha*

desjardinsi as preying upon this symphilid in Hawaiian pineapple lands. Wymore (121) mentions four species of true centipedes that feed on the garden centipede in California. Filinger (26) discusses two others that seem to be important control factors in greenhouses in Ohio.

The Soil-nesting Termite

Coptotermes formosanus Shiraki

The Dry-wood Inhabiting Termite—House Termite

Kalotermes (Cryptotermes) piceatus Snyder

Distribution: Coptotermes formosanus, probably immigrant from the Orient, where it occurs in Japan, Formosa and South China. *Cryptotermes piceatus* perhaps indigenous in Hawaii, occurs also in the Marquesas, Light (66).

Injury: Coptotermes formosanus, the more injurious and rapid worker of the two, nests in large colonies underground and destroys woodwork in the ground as well as above, tunneling out large irregular galleries chiefly parallel to the grain of the wood. Long cover-ways may lead along cement walls, etc., to woodwork, far removed from the nest.

Cryptotermes piceatus, a smaller species, nests in walls of houses, furniture, etc., in relatively small communities, of which, however, many may be present in a given area. It works rather slowly.

Nearly any sapwood is liable to attack by termites although redwood *(Sequoia)* is relatively immune. Termites move from place to place naturally through nuptial flights. They are also distributed through infested lumber.

They are guarded against through poisons and termite proofing of buildings. Here in Hawaii they have few obvious enemies aside from the common *Pheidole megacephala* ant. Elsewhere in the tropics termite raiding ants, *Odontoponera transversa* Sm. of the orient, *Neoponera commutata* (Roger) of Brazil and *Megaponera foetens* F. of Africa, do some good in reducing these pests. These are large stinging ponerine ants and probably would not succeed in Hawaii. *Ochromyia* flies are also termite enemies, so are certain phorid flies. Ant-eaters and some birds consume quantities of termites. Nematodes and fungi may also be listed as parasites of termites. However, it appears that there has not yet been found an efficient natural enemy of termites.

Further references: Ehrhorn (20), Van Zwaluwenburg (115), Pemberton (74), and Williams (119, pp. 164-165).

Beetle or Cypress Roach

Diploptera dytiscoides (Serville)

Described from Australia, also found in Fiji, New Guinea, Singapore, Ceylon, Marquesas, Ascension Isl., etc., and as an immigrant in Hawaii.

Of gregarious habit, it is sometimes quite injurious to *Cupressus* and *Cryptomeria* trees, the bark of which it gnaws, often with a girdling effect. It also attacks algaroba, lime, and other plants.

This roach is vivaparous, thus eliminating the possibility of egg parasites. In Hawaii, *Bufo marinus* and probably the mynah bird feed upon it. No effective enemy, however, is known. In other countries some cockroaches are preyed upon by ampulicid and sphecid wasps. A rhipiphorid beetle attacks *Blatta germanica,* Stamm (91), and it is possible *Diploptera* has a similar enemy.

Burrowing Roach

Pycnoscelus surinamensis (Linnaeus)

This roach is common, but not in habitations. It seems to have been first recorded from the Hawaiian Islands in 1882, although present many years previous. It is circumtropical in its distribution, but is found in subtropical regions also. Apparently of American origin, although several Asiatic species of the genus are known, Hebard (44, pp. 192-197). The insect produces no external egg capsule, but gives birth to a number of young at one time.

It is a vector of the eye worm of poultry, Alicata (1). It also does some injury to tender roots, tubers, and young plants.

In Hawaii, *Bufo marinus* feeds extensively on this roach and the mynah bird also preys upon it. In Haiti, the fly *Sarcophaga sternodontis* (Towns.) is a parasite upon it, Hoffman (46). This fly however is not a specific enemy. Ampulicid or sphecid wasps may perhaps prey upon this insect.

Garden Grasshopper

Atractomorpha ambigua Bolivar

This insect was described in 1905 from Shanghai, China. It first appeared in the Hawaiian Islands in about 1900, Perkins (78).

Here it is chiefly a garden pest; in the Orient a related species is bad on tobacco seedlings, Maxwell-Lefroy (67, p. 119). The life history of our species is given by Swezey (92).

No specific enemies seem to have been recorded for this genus which is represented in the Orient, Australia, and in Africa. Parasites in the egg capsules of *Atractomorpha* are likely to occur, and certain sphecoid wasps *(Prionony x)* in America prey on short-horned grasshoppers of several genera, Williams (117, pp. 227-230).

Tomato Blossom Bug

Cyrtopeltis varians (Distant) *(Engytatus geniculatus* Reuter)

First recorded from the Hawaiian Islands in 1924 by Swezey (99). General here at lower levels. Described from Guatemala. Probably native to tropical or subtropical America.

Damages tomatoes—sucking the flower stems, causing the flowers to drop off and the fruit not to set. Also breeds on tobacco here and in tropical America. Illingworth (50) has done work on its life history. This bug may also be predacious, Illingworth (51), Rosewall (84).

No specific enemies of this bug seem to have been recorded. Should it have parasites it might prove dangerous to introduce some of these in view of the fact that *Cyrtorhinus mundulus,* our most efficient sugar cane leafhopper enemy in Hawaii, belongs to the same family (Miridae) as this tomato blossom bug.

Corn Leafhopper

Peregrinus maidis (Ashmead) *(Pundaluoya simplicia* Distant)

A species of practically pantropic distribution occurring also in Southern United States and Hawaii, Muir (72, p. 147). Its native home is in doubt. In Hawaii it has been quite injurious since about 1880, Giffard (35, p. 116). Found on *Zea mais, Cynodon dactylon, Bromus unioloides, Sorghum vulgare,* and occasionally, *Saccharum officinale,* Kirkaldy (56, pp. 406-407). It stunts corn plants, and is the vector of corn stripe disease, Kunkel (64).

Fullaway (30, pp. 10-11) gives a brief life history of this insect in Hawaii.

In Guam, Swezey (107, p. 308) found *Cyrtorhinus lividus,* a leafhopper egg-sucking bug associated with *Peregrinus maidis.* In 1915, H. T. Osborn introduced the mymarid wasp *Paranagrus osborni* Fullaway from the Philippines. *Anagrus frequens* Perkins, parasitic in the eggs of the sugar cane leafhopper here also parasitizes *Peregrinus* eggs, Swezey (104, p. 290). Fullaway (32) reports having reared a dryinid wasp from the corn leafhopper.

The Cotton or Melon Aphis

Aphis gossypii Glover

The cotton aphis in Hawaii was first identified as such in 1909. It was common by that time and no doubt had already been in the islands for several years. It probably came to Hawaii from California where it has been known for over 50 years. It was first described from heavy infestations occurring on cotton in Georgia and South Carolina in 1854 and has subsequently spread to most of the states of the Union. It was early recorded on cotton in Brazil and to date is known to be present in most temperate and tropical parts of the world. It has a long list of host plants, numbering 50 or more, but is particularly destructive to cucurbits, such as melons, squashes and cucumbers, as well as commercial cotton and related plants. In Hawaii it has at times badly infested Irish potatoes, taro, cotton, hibiscus, eggplant, a number of ornamental garden plants and quite a list of weeds (113).

A number of predators and parasites attack this aphid in Hawaii, but more are known in various countries which would probably prove useful if introduced.

The Cowpea or Bean Aphis

Aphis medicaginis Koch

The bean aphis has also been in Hawaii 30 or more years. It was first identified here as this species in 1910. It is considered to be of European origin. It feeds chiefly on legumes, but has been recorded on a fairly wide range of host plants. It probably reached Hawaii from California, where it is a pest of economic importance. Because of its ruinous effect on cowpeas in these Islands, it is listed here as one of our important pests, requiring further control with imported natural enemies.

Hibiscus White Fly

Aleyrodes hibisci Kotinsky

This pest is rather generally distributed in the Territory of Hawaii where it was first recorded by Kotinsky (62, pp. 96-97). Kirkaldy (57) does not consider it endemic.

It is abundant on *hau (Paritium tiliaceum)* and on hibiscus.

In Hawaii the aphelinid wasp *Encarsia* sp. has been reared from *Aleyrodes hibisci,* Timberlake (112, pp. 435-436) and to this Fullaway (33, p. 113) adds the wasp *Eretmocerus corni* Hald. which often severely parasitizes this Aleyrodes. For aleyrodid enemies elsewhere, see Barnes (5). Material of the Hawaiian Hibiscus white fly was sent to Dr. R. Takahashi, Entomologist of the Government Research Institute, Department of Agriculture, Taihoku, Formosa, who pronounced the Hawaiian species to be identical with the Formosan *Dialeurodes hibisci* in a letter to C. E. Pemberton dated December 17, 1934. Dr. Takahashi stated that it is not abundant in Formosa. For this reason it may have efficient parasites in that region.

Lantana Blight—Lantana Scale

Orthezia insignis Douglas

A tropicopolitan insect and in greenhouses in temperate regions. Originally described from specimens on *Strobilanthes* "in the Royal Gardens at Kew," England. Its original home is doubtful. In the Hawaiian Islands, first found at Wailuku, Maui, by G. P. Wilder in 1899, Koebele (60). It damages a large number of dicotyledons, but is also reported from *Saccharum,* Morrison (71). An enemy of lantana in Hawaii.

The ladybeetle *Hyperaspis jocosa* (Muls.) was introduced into Hawaii from Mexico by Koebele in 1908 (63). At Nikko, Japan, Koebele (60) found a species of *Orthezia* attacked by *Hyperaspis* near *repensis.*

There appear to be no wasps parasitic on *O. insignis* known.

Green Coffee Scale—Green Bug

Coccus viridis Green

Described from Ceylon. Now a practically tropicopolitan insect. Considered native to Brazil, Dammerman (17, pp. 250-251). In Hawaii it was first discovered in Kona, in 1905, on citrus fruits by Kotinsky (61). It is injurious to coffee, citrus, gardenia, ixora, cacao, etc. The sooty mold that develops from the attack of this scale aggravates the damage.

In the Hawaiian Islands, the tropical American ladybeetle, *Azya luteipes* Muls. introduced here in 1908 from Mexico, Swezey (103) is sometimes effective, as also—more or less—the Australian *Orcus chalybeus* Boisd, and *Chilocorus circumdatus* Shon from China. Of parasites, the chalcid wasp *Prococcophagus orientalis* (Howard) is probably the best here, Timberlake (110, p. 404). In Ceylon, Green (38, p. 202) reports *Ceraptocerus ceylonensis* Howard.

Periodically, fungus greatly reduces *Coccus viridis.*

Coconut Scale

Pinnaspis buxi Bouche *(Pinnaspis pandani* Ckll.)

This insect, described from Europe from *Buxus sempervirens,* in 1851, occurs also in the West Indies, Brazil, and in greenhouses in temperate regions. It has been in Hawaii for many years. It is found on many kinds of plants including palms, pandanus, dracaenas, araceae, etc. In recent years it has been very injurious to coconut palms in Hawaii.

There is no satisfactory natural control of this pest here, although the little lady-beetle *Cryptogonus nigripennis* Weise, introduced by O. H. Swezey from Guam in November 1936, is promising, having already become well established on *Pinnaspis buxi* on coconut palms on Kauai. Mr. Swezey is publishing on this insect in the forthcoming Insects of Guam.

Of natural enemies elsewhere, Barnes (6, pp. 321-322) records the larvae of two species of midges—both from Ceylon—as being reared from plants infested with species of *Hemichionaspis* (=Pinnaspis). D. T. Fullaway, Territorial Entomologist, found the coccinellid *Pentilia egena* Muls. and the discolomid *Coccidophilus citricola* Brèthes to be important predators on *Pinnaspis buxi* at Rio de Janeiro. Efforts are under way to introduce these beetles into Hawaii.

Lima Bean Pod Borer

Maruca testulalis Geyer

The lima bean pod borer *Maruca testulalis* was first recorded as occurring in Hawaii on January 4, 1923, when Swezey (98) reported the finding of an infested garden pea pod obtained in a local Honolulu market December 9, 1922. Later he found a specimen in the Bishop Museum which had been collected on Tantalus by Professor Mosely of Ohio during August 1922. Mr. Swezey has since found it developing in the flowers of *Sesbania grandiflora* and in the seeds within the pods of lima beans, string beans, peas, pigeon peas, and the "Cowitch" *Mucuna urens.* This insect is an undesirable immigrant to Cuba and Puerto Rico, but does not occur within continental United States. It is known also in Java, Malaya, India, Burma, Ceylon, Uganda, Mauritius, and Samoa. Effective parasites are apparently unknown. A few of minor importance have been recorded in Cuba. Although the aggregate damage caused by it in Burma is considerable, it is listed as a pest of minor importance (87). At least one parasite has been found attacking it in India (27, p. 134).

Corn Earworm

Heliothis armigera Hb. *(obsoleta* F.)

The corn earworm or cotton bollworm is a notorious pest of green corn, which has girdled the globe within the parallels of 50 degrees north and south latitude (81, p. 13). Owing to its wide distribution, covering a long period of historic modern time, its original home is shrouded in obscurity. It was originally described in 1793 by Fabricius from material collected in the West Indies and it first gained notice as a pest in America, rather than some other region (81, p. 15). It sub-

sequently was found in many parts of the world and thus may possibly be of American origin. It has been known in the Hawaiian Islands 40 or more years. Strangely its host plants in Hawaii, which are many, did not include corn until about 1927, when Swezey (102) first found a caterpillar feeding in an ear of green corn. Previously it had been found feeding on tomato, cotton, eggplant, the flower heads of several compositae, certain weeds and some grasses, hibiscus flowers and buds, and a number of other plants. Commencing about 1931, damage became serious on corn. At that time Mr. Swezey reported about 50 per cent of the green ears of corn which he examined were infested with the caterpillars. Up to the present time the injury to the ears continues heavy. Swezey (108, p. 196) reported on May 2, 1935, that "The caterpillars feed chiefly in the ears of green corn, scarcely an ear of recent years but what is affected by them."

There are but few records of parasitism among corn earworms in Hawaii. Swezey (109) has reported finding larvae parasitized by *Hyposoter exiguae* (Vier.) and *Frontina archippivora* Will. Parasites and other natural enemies have been found attacking this insect in nearly every country where it has been studied. They are especially numerous in the mainland of the United States and have been mostly summarized by Quaintance and Brues (81, pp. 107-126). Many of these would be worth trying in Hawaii. Simmonds (90) records an unidentified species of *Apanteles* in Fiji, which is believed to be an effective parasite.

Coconut Leafroller

Omiodes blackburni (Butl.)

The coconut leafroller is generally considered a native Hawaiian insect, although the damage caused by it to coconut leaves is often so great, especially before certain foreign parasites became established, that it may be an old immigrant to the Islands. It has not been discovered outside the Hawaiian Islands, although allied species, referred to the genus *Nacoleia,* occur on other plants, mostly in India, Ceylon, and Malaya, some of which are known to be well parasitized. In support of the belief that it is endemic to Hawaii, Swezey (100, pp. 206-208) points out that *O. blackburni* and five other Hawaiian species of *Omiodes* occur on native species of bananas in Hawaii and that *blackburni* may have been in Hawaii before the coconut palm was introduced.

This insect often seriously damages the trees on the windward side of the Islands. Prolonged trade winds from the northeast apparently prevent the parasites of the leafroller from operating effectively wherever the trees are exposed to the wind. Quite a number of parasites operate on the coconut leafroller in Hawaii. Without some of them the damage to coconut trees would be very much greater and more continuous than it is at present. The four introduced parasites *Microbracon omiodivorum* (Terry), *Brachymeria obscurata* (Walk.), *Frontina archippivora* Will., and *Trichogramma minutum* were cited by Swezey (93, p. 37) as being the most important natural control factors in 1907. About 1910 the Oriental parasite *Cremastus flavoorbitalis* Vier. appeared in the Hawaiian Islands and attacked many different lepidopterous hosts, but especially the coconut leafroller. Often a high percentage of the caterpillars on the coconut leaves was found parasitized. By 1915

an improvement about Honolulu was noted and by 1917 the leafroller was at times quite scarce. This improvement seems to have resulted from the work of this new parasite and continues sporadically to date. *Cremastus* has difficulty during windy weather. However, more parasites are needed.

It is possible that some of the parasites of species of *Nacoleia,* occurring in India, Ceylon, and Malaya might attack the coconut leafroller if introduced to Hawaii. Known parasites of *Nephantis serinopa* Meyrick, a caterpillar which commonly feeds on coconut leaves in India, might also be worth investigating.

The Tortricid Leafroller

Amorbia emigratella Busck

This moth is considered a native of Mexico. It is also known to occur in Costa Rica and is probably also natural to other Central American regions. It is believed to have reached the Hawaiian Islands, probably from Mexico, about 1900. It was first identified as the Mexican species and named in 1909 by Busck (13) from material sent him by Mr. Swezey.

This insect rolls and feeds on the leaves of various trees, shrubs, vines and other plants. Fullaway (29, pp. 23-27) lists the following among its host plants: citrus trees, cotton, avocado, guava, rose, passion flower vine, tomato, papaia, cacao, sweet potato, and various indigenous plants in the mountains. J. F. Illingworth recorded the green caterpillars as common on young macadamia trees in Kona, Hawaii. Fullaway (29, p. 23) states that the wriggling, stout-bodied, green larvae sometimes become so numerous as to defoliate trees. Bryan (11) bred this moth from a caterpillar found boring in a seed capsule of an orchid *(Phaius* sp.) in Honolulu.

Several natural enemies attack this pest in Hawaii, but the control is not satisfactory. Various entomologists have recorded the following: *Nesodynerus rudolphi* (D.T.), *Odynerus nigripennis* (Holmgren), and *Pachodynerus nasidens* (Latreille), which store *Amorbia* and other larvae in their nests for larval food; *Trichogramma minutum* Riley, which is an egg parasite; the pupal parasites *Brachymeria obscurata* Walker and *Ecthromorpha fuscator* (Fabr.); the larval or possibly pupal parasite *Ephialtes hawaiiensis* (Cameron) and a predator *Xiphidiopsis lita* Hebard. Other parasites are most probably obtainable in Mexico or adjacent countries.

Koa Seed Worm or Litchi Borer

Argyroploce illepida (Butl.)

The koa seed worm or litchi borer is one of the early immigrant insect pests of Hawaii, having been found in the Islands when the first entomological collections were made. Originally known here as *Cryptophlebia illepida* (Butl.), it was not until 1910 that Meyrick (69, p. 218) established its identity as *Argyroploce illepida,* a species known in South Africa, India, Southern China, and Australia. This was positive and final evidence to support the feeling that it was not a native Hawaiian insect. It is a pest of major importance to *Acacia koa* in Hawaii, since its larvae destroy from 50 to 90 per cent of the koa seeds, as determined by Mr. Swezey. It also commonly infests the seeds of *Acacia farnesiana,* litchi, macadamia nut husks,

and the fruits of several other plants. There are times when the litchi crop is seriously damaged.

Parasites which have been reared from this pest in Hawaii include *Cremastus flavoorbitalis* Vier, *Ephialtes hawaiiensis* (Cameron) and *Microbracon pembertoni* Bridwell. More natural enemies are needed. They may occur in South India or Southern China where the damage to litchi has been reported to be light.

The Cabbage Webworm

Hellula undalis (Fabr.)

The imported cabbage webworm is considered as serious a pest of cabbage in Hawaii as the cabbage butterfly. It was in Hawaii as early as 1892 (31). It probably came from California in cabbages, for it was known in Los Angeles in 1891-92 (15). The date of its entry into the United States is not known, but by 1897 it had gained prominence as a pest of cruciferous plants through the Southern States to California. It now has a world-wide distribution within tropic and temperate zones. The larvae mine into the midribs of the host leaves, penetrate the stems and may enter the heart or bud of the growing plant, which prevents normal growth. Young plants may thus be killed outright (31).

Fullaway (31) reports one parasite *Chelonus blackburni* as commonly attacking this pest in Hawaii. Chittenden and Marsh (15) record at least five natural enemies occurring on the mainland of the United States. These would be worth trying in Hawaii. A few parasites have been reported from other parts of the world. It has been mentioned as a pest of minor importance in India, Burma, and Ceylon (*27*, p. 132). These regions would be the most promising for study in a search for natural enemies.

The Bean Butterfly

Cosmolyce boetica L.

The bean butterfly entered the Hawaiian Islands sometime prior to 1882. It is perhaps of Oriental origin, though it is now distributed over the whole of South and Central Europe, parts of Africa, Canary Islands, Madagascar, Western and Central Asia, Mauritius, Ceylon, India, Malaya, Java, Sumatra, Japan, and probably other parts of the Malay Archipelago and the Pacific. It is a pest of leguminous crops of many sorts. The larvae destroy the pods, seeds and flowers.

Two parasites of this insect are known in Hawaii but they are not sufficiently effective. The minute wasp *Trichogramma minutum* Riley parasitizes the eggs and Swezey (96, p. 105) reared the large ichneumonid *Ecthromorpha fuscator* (Fab.) from the pupae of the butterfly. Both parasites have many other insect hosts in the Islands. *Trichogramma minutum* is said to be effective on this pest in Sumatra. It may be a different strain or variety from the *Trichogramma* in Hawaii. Dr. F. X. Williams found parasites of related bean butterflies in the Philippine Islands in 1922. These were an ichneumonid which parasitizes the larvae, and an *Odynerus* sp. which stores its nests with lycaenid larvae (118, p. 175). The ichneumonid and the *Odynerus* were introduced into Hawaii and liberated but have evidently failed of establishment.

Cabbage Butterfly

Pieris rapae Linn.

The cabbage butterfly, or cabbage worm, has been in Hawaii at least since 1898. It was positively identified by Meyrick (68) in 1904. Perkins (79, p. cxliv) writing in June, 1909, states: "The Pierid, *Pieris rapae* was imported with cabbages from California some 12 years ago." It is of European origin, having first appeared in Quebec, Canada, about 1860, the State of Maine in 1865, and by 1883 it had reached California. The larva feeds on cruciferous plants and is particularly destructive to cabbage.

Several natural enemies attack the cabbage worm in Hawaii, but additional control is needed unless the present established parasites gain considerable headway in the immediate future. Of the established parasites *Apanteles glomeratus* (Linn.) is probably the most important. It was imported into America from Europe in 1883 and from the Atlantic Coast to Hawaii in 1898 and 1928 (101) and from Japan in 1923 (106). Swezey (106) first found it established in 1934. This was at Kilauea, Hawaii. Dr. C. Schmidt reported its establishment on Maui in 1936 and Dr. F. G. Holdaway announced the recovery of this parasite on Oahu in 1938. The tachinid fly *Frontina archippivora* Will., attacks the larvae of a number of lepidopterous insects, including the cabbage butterfly, as demonstrated by Swezey (106). This fly has been in Hawaii at least since 1895. Another parasite *Brachymeria obscurata* (Walk.), introduced from Japan about 1895, has several lepidopterous hosts in Hawaii. It has been reared from the pupae of the cabbage worm. The large *Polistes* wasps, early immigrants to Hawaii, use chewed up portions of cabbage worms and other caterpillars as food for their young.

In the event the above parasites and predators do not accomplish a satisfactory control of this pest, other known parasites occurring in America or Europe would be worth trying in Hawaii. An important parasite *Pteromalus puparum* (L.) has been introduced from California and bred in large quantities for liberation, but has apparently failed of establishment. This work was conducted by the entomologists of the Territorial Board of Agriculture and Forestry during 1919.

Hibiscus Midge

Contarinia maculipennis Felt.

This midge recorded thus far only from Hawaii, Oahu, and Kauai, was first bred from hibiscus buds by Swezey in November 1931 (105). It distorts these flower buds and often causes them to fall off. It has also been found on buds of *Jasminium sambac* (Fullaway, 34).

There appear to be no parasites on our hibiscus midge although related species elsewhere are parasitized by chalcidid wasps. For data on these, see Ballard (4), Barnes (7), and Ferrière (23).

Horn Fly

Lyperosia irritans (Linnaeus)

This pest of cattle breeds in cattle manure. It is a biting fly and accumulating in large numbers on its host irritates and weakens it by its bites and feeding. Widely

distributed in Europe and occurring also in Asia Minor, it was first discovered in America in 1887, and in Hawaii in 1898, Koebele (59). The life history has been worked out by Riley and Howard (82) and by others.

Natural enemies are of two types: dung scatterers, and direct enemies (parasites and predators). A. Koebele was the chief worker here for Hawaii, see Swezey (94). One of the parasites introduced by him is the German braconid wasp *Bathymetis* sp. *Spalangia philippinensis* was introduced by Fullaway.

For enemies preying on the related *Lyperosia exigua,* not occurring in Hawaii, see Ferrière (24) and Handschin (41, 42, and 43).

Melon Fly

Dacus cucurbitae (Coquillet)

Introduced here from the Orient in about 1895, Back and Pemberton (2). It is well distributed in the Orient. Bezzi (9, pp. 96-97) considers it to be native of India. For its distribution see Shiraki (86, pp. 96-97).

Its plant hosts are chiefly Cucurbitaceae; but Solanaceae and certain Leguminosae (string beans and cow peas) are also attacked.

In Hawaii, the braconid wasp, *Opius fletcheri* Silvestri (89, p. 163) introduced from India in 1916 is a larval parasite. Other *Dacus* parasites exist in India, Hadden (40). For information on dacine flies in West Africa, see Van Zwaluwenburg (116, pp. 78-83) and in East Africa, see Bianchi and Krauss (10). None of the recently introduced fruit or melon fly parasites have yet been recovered.

Pineapple Beetle

Carpophilus humeralis (Fabr.)

Though not confined strictly to decaying pineapples and pineapple stumps, *Carpophilus humeralis* is vastly more abundant in pineapple lands than elsewhere in Hawaii. This beetle develops to literally millions in rotting pineapple stumps following harvest. From there they fly into cane lands where they develop in souring cane material and often become a general and aggravating nuisance to the labor in the fields. The beetles often mass at the cut ends of planted cane seed pieces underground and during the winter months, when germination is slow, hasten fermentation of the pieces and interfere with the germination.

This nitidulid beetle is considered native to tropical Africa, but has become cosmopolitan through the transportation of fruits and other plant material in which it can live when such hosts are moved in a spoiled or decaying condition. No parasites or other natural enemies occur in Hawaii. Silvestri (88) described and figured in 1915 an internal parasite which he discovered parasitizing nitidulid larvae of supposedly *Carpophilus* species, occurring in fallen fruit at Conakry, French Guinea, West Africa. This parasite should be tried in Hawaii.

The Chinese Rose Beetle (Japanese Beetle)

Adoretus sinicus Burm.

The Chinese rose beetle, commonly called in Hawaii the Japanese beetle, is not a native of Japan. It is known to occur in Southeastern Asia, Java, Formosa,

Timor, and Hawaii. It is believed to have been introduced into Hawaii some years prior to 1896. It almost certainly entered in the grub stage in soil brought in from China. The adult heavily defoliates many ornamental plants, shrubs, trees, vines, and truck crops in Hawaii at certain seasons of the year. The grub apparently restricts its food to decayed organic matter.

A number of different parasites for control of this beetle have been introduced into Hawaii from the Philippine Islands, Formosa, and Japan without successful establishment. The Scoliid wasp *Campsomeris marginella* sub-species *modesta* Sm. *(Scolia manilae* Ashm.), introduced from the Philippine Islands for the control of *Anomala orientalis* in 1916, parasitizes the grubs of the rose beetle in Hawaii and accomplishes a very considerable reduction in the population of the pest, but the control is insufficient and more natural enemies are needed. The toad *Bufo marinus,* an introduction in 1932, is playing a further part in checking the beetle, but the establishment of additional predators or parasites is necessary.

Fuller's Rose Beetle

Asynonychus godmani Crotch *(Aramigus fulleri* Horn)

This weevil was first recorded in Hawaii in 1894, Koebele (58). It occurs also in California, Mexico, Brazil, Argentina, Chile, the Azores, Portugal, Sicily, etc. It is considered of American origin. The adult is injurious to flowers and foliage of many kinds. On the mainland of the U. S. A. and in Brazil it is an injurious feeder on roots in the larval stage.

In Hawaii the larva of *Conoderus exsul,* our common click beetle, is an enemy of the young of Fuller's rose beetle in the ground.

Fossorial wasps of the genus *Cerceris* have long been known to store their deep tunnels in the ground with various groups of beetles, of which weevils are among the most common provender. These wasps are often not specific in the selection of this prey, family limits apparently being sufficient in some cases, Williams (119, pp. 152-153).

Sweet Potato Weevils

Euscepes postfasciatus Fairm. *(E. batatae* Waterh.)

Cylas formicarius Fab. var. *elegantulus* Summers

These two weevils have been in Hawaii a long time. They probably arrived in imported sweet potatoes brought to the islands over 50 years ago. The larvae of both bore extensively in the tubers and often render them unfit for food. They also work in the stems of the plants. *Cylas formicarius* also readily breeds in the stems of the beach morning-glory *Ipomoea pes-caprae* (29, p. 29). Swezey (97) has found that *Euscepes postfasciatus* can breed in the stems of a Japanese morning-glory in Hawaii also.

Euscepes postfasciatus has been found in many of the West Indian islands, Brazil, British Guiana, Peru, Hawaii, Guam, Fiji, Caroline Islands, New Zealand, and China. A rigid quarantine is maintained in the mainland of the United States against sweet potatoes produced in countries where this pest occurs. No parasites

or other important natural enemies are known to attack this insect, though extensive search for such control factors has apparently not been made. It is assumed to be native to some South American region.

Cylas formicarius has a very wide distribution throughout the tropics and subtropics of America, Africa, India, the Orient, and Pacific islands. Two parasites of minor importance are known to attack it in the Philippine Islands (36, p. 278). Though generally considered indigenous to India, it is rated as a serious pest of sweet potatoes there. Several species of the genus are known in Africa, though no parasites have been recorded from them in that part of the world. It is possible that natural enemies may occur in Africa, however.

Mango Weevil

Cryptorrhynchus mangiferae Fab.

The mango weevil was first seen in the Hawaiian Islands on July 5, 1905. J. E. Higgins found a pupa in a mango seed in Honolulu. Van Dine (114), writing in detail on its early history in Hawaii, world distribution and habits, expressed the opinion that it undoubtedly came to the Islands after 1898 and that it was most probably introduced in mango seeds or other plant material imported from India or the Philippine Islands. This weevil has a wide distribution within the tropics, which includes parts of Africa, Madagascar, India, Ceylon, Java, Malaya, Philippine Islands, and Hawaii.

A high percentage of mango seeds in Hawaii is usually infested with the larvae of this weevil. The larvae enter the seeds of green fruit and it is generally conceded that such infestation induces a premature falling of the fruit. Van Dine states that no natural enemies of this insect have been observed. Like the mango, it is probably of Indo-Malayan origin and natural control factors such as parasites and predatory enemies, may be expected to occur somewhere within this region. Species assigned to the genus *Cryptorrhynchus* are, however, most numerous in South and Central America.

Orchid Weevil

Orchidophilus aterrimus Waterh. *(Acythopeus aterrimus* Waterh.)

This dull black weevil, measuring from 1/8 to 1/7 inch in length, is the largest of the several species of orchid weevils that have been found in Hawaii at various times on orchids imported from several countries. It was evidently introduced in orchids imported from the Philippine Islands about 1910 or earlier. Swezey (95) records the first proof of establishment on May 5, 1910. This species attacks a wide range of orchid species, comprising a number of genera. It is now well intrenched in Hawaii both in greenhouses and outdoors. Dr. H. L. Lyon finds it infesting the common *Spathoglottis plicata* outdoors. The adults feed on the young leaves and flowers but the serious damage is done by the larvae which bore extensively in the pseudo-bulbs.

Buchanan (12) is of the opinion that the genus is indigenous in the upper Malayan region because of the frequency with which *aterrimus* and the other species of the genus are taken from orchids imported from the Philippine Islands or the

Straits Settlements. It is here that parasites probably occur, though none have been recorded.

Carpenter Bee

Xylocopa varipuncta Patton

The carpenter bee *Xylocopa varipuncta* was common in the vicinity of Honolulu as long ago as 1880. Its correct identity was established and announced by Timberlake (111) at a meeting of the Hawaiian Entomological Society on January 6, 1921. This bee is considered an important pollinator of edible *Passiflora* species in Hawaii, but it bores so extensively in building timbers, fence posts, telephone poles, etc., especially if such are made of California redwood *Sequoia sempervirens,* that it is rated a pest of considerable importance by many residents of the Territory. The bee is native to Southwestern United States. Members of the family *Xylocopidae* occur mostly within the tropics and semi-tropics of such widely separated regions as Europe, Africa, Asia, India, Malaya, and the Americas.

A number of natural enemies of bees of the genus *Xylocopa* are known. The meloid beetle *Cissites auriculata* Champion destroys *Xylocopa* nests in tropical America. This beetle was introduced into Hawaii from Guatemala by F. A. Bianchi in 1935, though to date there is no evidence of establishment. Green (37) has described the habits of a similar beetle *Cissites testaceus* F. occurring in nests of *Xylocopa tenuiscapa* Westw. in Ceylon. The callimomid parasite *Monodontomerus montivagus* Ashmead has been recorded (18) as a larval parasite of *Xylocopa orpifex* Smith in Southern California. Two species of bombyliid flies *Spogostylum delila* (Loew) and *S. simson* (Fabr.) are known as natural enemies of the same carpenter bee in California (21), together with a mite *Trichotarsus xylocopae* Donn. ?, which was found attacking larvae of *Xylocopa varipuncta.* Asilid flies of the genus *Hyperechia* have been found developing within *Xylocopa* burrows in India and East Africa with definite evidence that their larvae fed on the bee larvae (80), (54). Dover (19) and Kannan (54) have discussed a minute encyrtid parasite, whose larvae completely fill *Xylocopa* larvae in British India. Mr. Pemberton reared hundreds of quite a similar parasite from *Xylocopa* larvae collected at Menado, North Celebes, during 1926.

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Sugar Prices

96° CENTRIFUGALS FOR THE PERIOD
MARCH 16, 1938 TO JUNE 14, 1938

Date	Per Pound	Per Ton	Remarks
Mar. 16, 1938..	3.01¢	$60.20	Philippines.
" 20	3.05	61.00	Puerto Ricos.
" 22	3.005	60.10	Philippines, 3.01, 3.00.
" 24	2.965	59.30	Philippines, 2.97, 2.96.
" 29	3.00	60.00	Puerto Ricos.
Apr. 4	2.98	59.60	Puerto Ricos.
" 5	2.96	59.20	Cubas.
" 6	2.95	59.00	Puerto Ricos, Philippines.
" 8	2.89	57.80	Puerto Ricos, 2.90; Puerto Ricos, 2.88; Cubas, 2.88.
" 11	2.855	57.10	Puerto Ricos, 2.86, 2.85; Philippines, 2.85.
" 12	2.815	56.30	Puerto Ricos, 2.82; Philippines, 2.82, 2.81.
" 22	2.81	56.20	Puerto Ricos.
" 23	2.80	56.00	Philippines.
" 27	2.835	56.70	Puerto Ricos, 2.85; Philippines, 2.82.
" 29	2.81	56.20	Puerto Ricos.
May 2	2.82	56.40	Puerto Ricos.
" 3	2.805	56.10	Philippines, 2.80, 2.81.
" 5	2.80	56.00	Philippines.
" 6	2.75	55.00	Philippines.
" 18	2.70	54.00	Puerto Ricos, Philippines.
" 20	2.68	53.60	Philippines.
" 23	2.65	53.00	Philippines.
June 3	2.70	54.00	Puerto Ricos.
" 6	2.72	54.40	Puerto Ricos.
" 7	2.70	54.00	Philippines, Puerto Ricos.
" 9	2.715	54.30	Puerto Ricos, 2.73, 2.70; Philippines, 2.70.
" 14	2.70	54.00	Philippines.